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MORTALITY RATES IN THE CALIFORNIA STRIPED BASS POPULATION¹

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Mortality rates for the Sacramento-San Joaquin River system striped bass (*Morone saxatilis*) population were calculated from tag returns. Annual variations and variations among different parts of the population were examined.

INTRODUCTION

A gradual decrease in sport fishing success for striped bass during the late 1940's and early 1950's (Chadwick, 1962) caused considerable concern over the population's status. As part of a program to evaluate changes in the population and regulations, a 4-year tagging program was started in 1958 to measure mortality rates. This paper describes and evaluates these mortality rates. Angling regulations will be evaluated in light of these estimates in a subsequent paper.

An earlier tagging study (Calhoun, 1952) did not yield satisfactory mortality estimates, largely because of the loss of tagged bass in commercial salmon and shad gill nets. These commercial fisheries were closed in 1957, and bass in the present study were not affected significantly by any commercial fishery.

This study involves only California's main striped bass population, which inhabits the Sacramento-San Joaquin river system. Adults spawn in the Sacramento-San Joaquin Delta and its main tributaries in the spring, migrate downstream to brackish and saltwater bays and the Pacific Ocean immediately afterwards, and return to the Delta either in the fall or the following spring (Calhoun, 1952; Chadwick, 1967).

METHODS

Most striped bass tagged in this study³ were caught during April, May, and early June in drift gill nets fished at several locations near the junction of the Sacramento and San Joaquin Rivers (A through E, Figure 1). These tagging areas are referred to as the western Delta throughout this paper. Small groups of bass were also tagged there in the falls of 1957 and 1958. Additional fish were caught for tagging in wire fyke nets (Haddock et al., 1957) at Fremont Weir on the upper Sacramento River (F, Figure 1) in May 1958, in drift gill nets at Prisoners Point in the eastern San Joaquin Delta (G, Figure 1)

¹ Accepted for publication May 1968. This study was performed as part of Dingell-Johnson Project California F-9-R, "A Study of Sturgeon and Striped Bass", supported by Federal Aid to Fish Restoration Funds.

² Now with Delta Fish and Wildlife Protection Study.

³ See Chadwick (1960, 1963, and 1967) for more detailed descriptions of fishing gear, fishing methods, tags, and tagging methods.

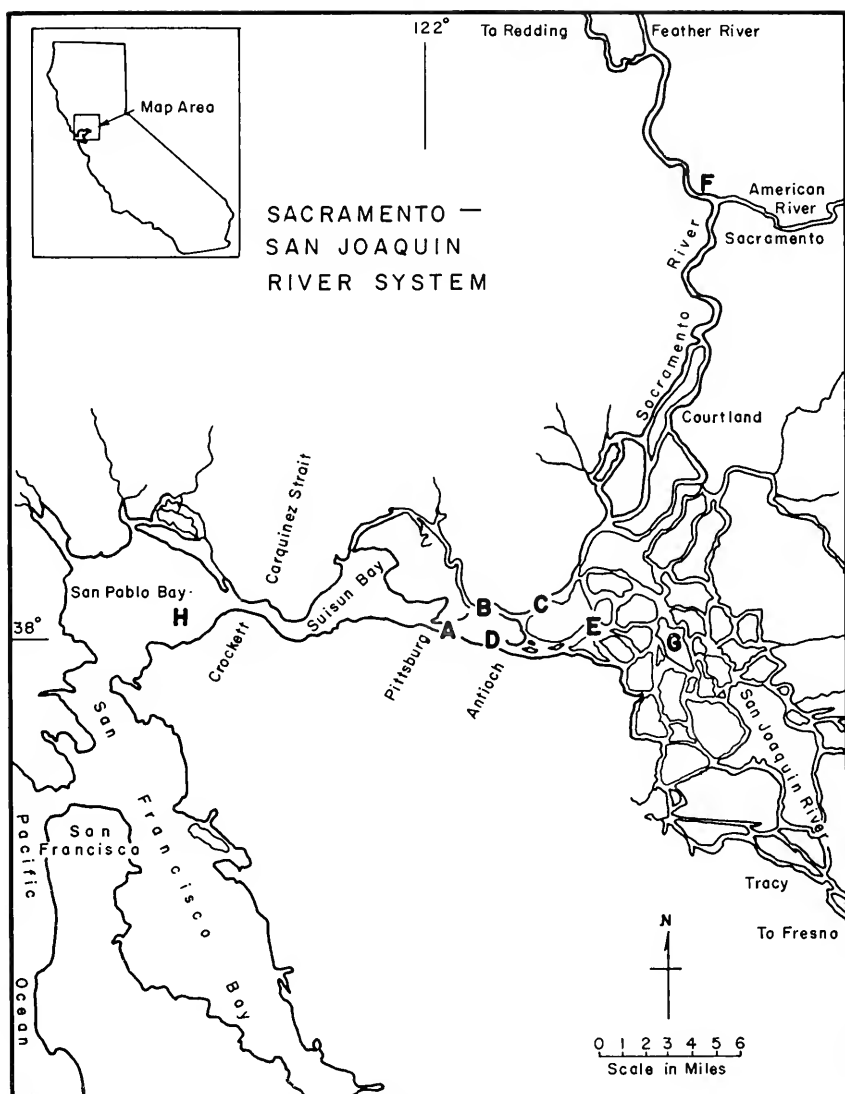


FIGURE 1—Map of study area showing tagging sites. A, Sacramento River at Chipps Island; B, Sacramento River at Chain Island; C, Sacramento River at Sherman Island; D, Broad Slough; E, San Joaquin River at False River; F, Sacramento River at Fremont Weir; G, San Joaquin River at Prisoners Point; H, San Pablo Bay.

in the spring of 1959, and by angling in San Pablo Bay (H, Figure 1) in the falls of 1958 and 1959.

Bass were tagged with several kinds of tags, but most were tagged with disk dangler tags. This tag proved to be superior or equal to the

other types (Chadwick, 1963), and was the only type used in estimating mortality rates. Disk dangler tags are modified Atkins tags (Calhoun, 1953, Figure 3). In this study, these tags consisted of a cellulose nitrate disk attached with pure tantalum or soft stainless steel wire through the back below the first dorsal fin (Chadwick, 1963).

Some of the disk dangler tags had the wording "\$5 REWARD" printed on the face of the tag. In 1958 this wording was red, while the remainder of the printing was black and the tags were white. In subsequent years, some of the reward tags were orange with black letters. Nonreward tags were white with black letters.

In 1958, reward tags were applied in a ratio of 1:2 with a group of nonreward tags. In subsequent years the ratio was 1:4. In each case, the two types of tags were applied systematically, so the two groups were comparable. For example, in 1958 one fish received a reward tag, the next two received nonreward tags, the next a reward tag, etc., until the number quota was reached.

In addition to the type of tag, the date, the fork length to the nearest inch, the tagger, the type of fishing gear, and the fish's condition were recorded for each tagged fish. Fish which swam away immediately upon release were considered to be in good condition. Those which floated at the surface for a period ranging from a few seconds to several minutes after release were considered to be in poor condition. Fish which bled profusely from the tagging wound were placed in a third condition category. This bleeding was caused by puncturing blood vessels in the vicinity of the neural spines.

Since bass were tagged over approximately 2 months each spring while sportsmen were fishing, the year of recovery for each tag was determined by the number of elapsed days between tagging and recapture. When anglers did not report date of recapture, a postcard questionnaire was sent to try to determine this date. In the few cases when this failed, the date of recapture was assumed to be the postmark date on the angler's letter. Tags with 0 to 365 elapsed days were recorded as first-year recoveries, those with 366 to 730 days as second-year recoveries, etc. Thus, recovery years do not pertain to any precise calendar period, but generally run from spring to spring.

Designating year of recovery in this manner could affect mortality estimates significantly for a fishery that is highly seasonal. However, in this case relatively few bass were recaptured while tagging was in progress. In 1961, 8.2% of the first-year recoveries were made while tagging was in progress, while in other years this percentage ranged from 2 to 3.5%.

Also, an analysis later in this paper (see Table 6) shows that percentage returns are not related to time of tagging. Hence, apportioning recoveries in this manner has no significant effect on mortality estimates.

In general mortality rates were estimated following Ricker (1958), but several modifications were made.

The proportion of all recaptured tags which were returned was estimated from the formula:

$$\hat{r} = \frac{M'R''}{R'M''} \quad [1]$$

where:

- \hat{r} = proportion of recaptured tags returned,
- M' = number of reward tags applied,
- R' = number of tags returned during first year from group M' ,
- M'' = number of nonreward tags applied to a group of fish comparable to group receiving reward tags,
- R'' = number of tags returned during first year from group M'' .

The variance of this estimate of response was estimated from the formula:

$$V(r) = \left(\frac{P''}{P'} \right)^2 \left(\frac{Q''}{M''P''} + \frac{Q'}{M'P'} \right) \quad [2]$$

where the new symbols are:

- $V(r)$ = estimated variance of response,
- P'' = proportion of tags M'' returned during first year,
- Q'' = proportion of tags M'' not returned during first year,
- and P' and Q' are comparable proportions for tags M' .

This formula for variance is adapted from formulas 10.4 and 18.1 (Hansen, Hurwitz, and Madow, 1953, Chapter 4). The proportion of nonresponse is equal to $1 - r$, and the variance of nonresponse is equal to the variance of response. Confidence limits were estimated assuming a normal distribution.

Annual response estimates were weighted by the reciprocal of their variances when estimating the mean response for the four years according to the formula:

$$\bar{r} = \frac{\sum_{i=1}^4 \frac{\hat{r}_i}{V(r)_i}}{\sum_{i=1}^4 \frac{1}{V(r)_i}} \quad [3]$$

where the subscript i denotes time in years and ranges from 0 to t . In all cases where i is used to designate time for a process occurring over a period of time, the time it designates is from $i - 1$ to i .

Rates of exploitation were then estimated using the formula:

$$\hat{u}'_i = \frac{R_{(i-1)i}}{rM_{(i-1)}} \quad [4]$$

where new symbols are:

\hat{u}'_i = rate of exploitation from $i - 1$ to i .

M_i = number of nonreward tags applied at i .

R_{ij} = number of nonreward tags applied at time i and recaptured during time j , with j ranging from 1 to t .

The variance of the proportion of tags returned was calculated from the formula:

$$V(\hat{u}_i) = \frac{R_{(i-1)i}}{(M_{(i-1)})^2} \left(1 - \frac{R_{(i-1)i}}{M_{(i-1)}} \right) \quad [5]$$

where \hat{u}_i is the proportion of $M_{(i-1)}$ tags actually returned from $i - 1$ to i .

The approximate formula for the variance of the rate of exploitation was developed following Lindley (1965, p. 134-139). The formula is:

$$V(u'_i) \approx \left(\frac{1}{r} \right)^2 V(u_i) + \left(\frac{\hat{u}_i^2}{r^4} \right) \frac{\sum_{i=1}^n V(r)_i}{n^2} \quad [6]$$

Confidence limits were calculated assuming a normal distribution.

Returns indicated that survival was not constant so survival and its variance in 1958, 1959, and 1960 were estimated following Jolly (1965), using the following formulas:

$$\begin{aligned} & \hat{M}_{i(0+1+\dots+(i-1))} \\ &= M_i \frac{(R_{0((i+1)+)} + R_{1((i+1)+)} + \dots + R_{(i-1)((i+1)+)})}{R_{i((i+1)+)}} \end{aligned} \quad [7]$$

$$\begin{aligned}
 \hat{s}_i &= \frac{\hat{M}_i^{(0+1+\dots+(i-1))}}{(\hat{M}_{(i-1)}^{(0+1+\dots+(i-1))} + M_{(i-1)})} \quad [8] \\
 V(\hat{s}_i) &= \hat{s}_i^2 \left[\frac{\hat{M}_i^{(0+\dots+(i-1))} (\hat{M}_i^{(0+\dots+(i-1))} + M_i)}{(\hat{M}_i^{(0+\dots+(i-1))})^2} \left(\frac{1}{R_{i((i+1)+)}} - \frac{1}{M_i} \right) \right. \\
 &\quad + \frac{\hat{M}_{(i-1)}^{(0+\dots+(i-1))}}{(\hat{M}_{(i-1)}^{(0+\dots+(i-1))} + M_i)} \left(\frac{1}{R_{(i-1)i+}} - \frac{1}{M_{(i-1)}} \right) \\
 &\quad \left. + \frac{(1 - \hat{s}_i)}{\hat{M}_i^{(0+\dots+(i-1))}} \right] \quad [9]
 \end{aligned}$$

where the new symbols are:

$\hat{M}_i^{(0+1+\dots+(i-1))}$ = Estimate of number of tagged fish surviving from releases at times 0, 1, . . . , $i - 1$ to time i .

R_{ij+} = number of bass tagged at time i which are recaptured in year j and all subsequent years.

\hat{s}_i = estimate of probability of survival from time $i - 1$ to time i .

These formulas are analogous to Jolly's formulas 22, 24, and 27, respectively. They differ in not having the number of tagged fish recovered (Jolly's m_i) subtracted from estimates of the numbers of tagged fish alive, and in having the notation changed to correspond more closely to Ricker's notation. The numbers of tagged fish recovered were not subtracted because tag recoveries were not made coincident with subsequent tagging operations.

Since both natural mortality and fishing mortality varied, precise estimates of survival and natural mortality could not be made after the third year and fishing mortality could not be estimated precisely after the fourth year. Mortality rates through the spring of 1965 were approximated by:

- 1) Estimating survival for 1961 by dividing the estimated total recaptured in 1962 by the estimated total in 1961. This was multiplied by the number of fish estimated to be alive at the beginning of 1961 ($M_3^{(0+1+2)} + M_3$) to estimate the number alive at the beginning of 1962.
- 2) Estimating the number caught during 1962 by dividing the number of tags returned in 1962 by the mean response estimate (equation 3). Then estimating the rate of exploitation during 1962 by dividing the estimated number caught during the year by the number estimated to be alive at the beginning of the year.
- 3) Averaging expectations of deaths from natural causes for 1958 through 1961, and assuming that this remains constant from 1962 on.
- 4) Subtracting the estimated rate of exploitation plus the mean expectation of deaths from natural causes from 1 to estimate survival rate, and multiplying this by the number alive at the beginning of the year to estimate the number surviving at the end of the year.
- 5) Repeating steps 2 and 4 for each subsequent year.

VALIDITY OF ESTIMATES

Mortality estimates based on tag returns are accurate only if the tags do not cause mortality, do not affect vulnerability to fishing, are not shed, are returned when the fish are caught, and are randomly distributed in the population. Study results do not permit a precise evaluation of all of these, but pertinent findings will be reviewed to give the reader an understanding of the estimates' limitations.

Effects on Mortality

The gill nets were not drifted longer than 20 minutes and fish obviously in poor condition were not tagged, to minimize immediate mortality from handling and tagging. Nevertheless some fish died shortly afterward, presumably as a direct result of handling and tagging. Each year anglers and the tagging crew picked up a few dead bass within a week after tagging. For example, in 1958, 8 of 4,386 tagged bass were found dead. This is the only direct evidence of mortality.

The mean blood lactic acid level⁴ in 6 bass caught in the gill net in June 1959 which were in good condition was 630 mg/l. In contrast, the mean level in 12 bass caught at the same time, but which were in poor condition, was 1,170 mg/l. Only one fish in the first group fell within the range of the latter group. The mean level in 10 bass caught by angling in October 1959 was 230 mg/l. These levels indicate that the arbitrary classification by condition reflects real physiological differences, and that even fish in good condition when removed from

⁴Determined by method of Barker and Summerson (Hawk, Oser, and Summerson, 1949).

the net have increased blood lactic acid, presumably as a result of fatigue.

Returns from fish in different conditions at release provide indirect evidence of mortality (Table 1). In 1958 and 1960 returns differed significantly among the three groups ($\chi^2 = 8.66$, $P = 0.014$, and $\chi^2 = 6.69$, $P = 0.038$, respectively). This was caused primarily by low returns from fish in poor condition. This did not occur in 1959 and 1961, and returns did not differ significantly among the three groups in those years.

TABLE 1
Relationship Between Condition at Tagging of Striped Bass
and Percentage Returns *

Condition	Returns from each year's tags			
	1958	1959	1960	1961
Good-----	23.2 (3653)	14.9 (2870)	14.4 (3262)	11.4 (1565)
Poor-----	16.2 (321)	15.6 (308)	8.8 (205)	12.9 (85)
Bleeding from tagging wound-----	21.0 (238)	22.1 (95)	18.8 (96)	18.2 (44)

* Includes only first year returns from nonreward tags on striped bass tagged in the western Delta during the spring. Numbers in parentheses are numbers of tagged bass.

The low 1958 and 1960 returns from fish in poor condition were presumably caused by mortality resulting from tagging and handling. I have no explanation for the mortality being inconsistent. Because of this evidence, fish in poor condition when tagged were eliminated from all mortality estimates.

Bleeding at the time of tagging obviously did not increase mortality.

Bass tagged with disk dangler tags generally grew more slowly than untagged bass (Chadwick, 1963), but this would not necessarily have caused greater mortality.

Disk dangler tags sometimes caused considerable irritation, often as the result of hydroids attached to the tag (Chadwick, 1963). There is no way of knowing whether this caused mortality, but fish were seen with large scars near the tag, indicating recovery from considerable tissue damage. Observations indicate that tissue damage from the tags was greatest in the first year after tagging.

Vulnerability to Fishing

Tagging and handling reduced the vulnerability of bass to angling for about a month after tagging (Chadwick, 1963). The monthly ratios of returns from bass tagged in one year to those tagged the previous year during 4 months after the later group was tagged indicate that vulnerability was reduced by about a third to a half during the first month after tagging.

To estimate the maximum error from this source, vulnerability during the first month was assumed to have been reduced by half. To approximate the effects of this the number of tags received in the first 30 days after tagging (Chadwick, 1963, Table 11) was doubled. This would have increased angling exploitation rates in 1958, 1959, 1960, and 1961 by about 3, 4, 4, and 8%, respectively. The actual increase would have been less because some of the fish which had been saved by the lower vulnerability would have been caught later in the year, and because this assumes the maximum observed error. Hence, errors from this source are small.

Tag Shedding

While disk dangler tags have proved equal or superior to several other types of tags tested, a few have been shed under various circumstances (Chadwick, 1963).

Results from the earlier years of the study suggested that apparent survival was greatest for the most recently tagged fish, indicating that either shedding rate increases with time after tagging or mortality is greater for older fish (Chadwick, 1963). However, more recent results (Table 2) suggest that survival is not related to length of time

TABLE 2
Ratios of Tag Returns in Successive Years From Tags
Applied in Different Years *

Years for which ratios were calculated	Year tagged			
	1958	1959	1960	1961
1960-1959	0.50 (103)	0.59 (266)		
1961-1960	0.50 (52)	0.42 (111)	0.52 (261)	
1962-1961	0.52 (27)	0.80 (89)	0.61 (158)	0.70 (131)
1963-1962	0.52 (14)	0.69 (61)	0.92 (145)	0.89 (117)
1964-1963	0.86 (12)	0.33 (20)	0.41 (59)	0.45 (53)
1965-1964	0.58 (7)	0.60 (12)	0.59 (35)	0.40 (21)
1966-1965	1.11 (8)	1.42 (17)	0.95 (33)	1.19 (25)

* Includes only nonreward tags from fish in good condition which were tagged in the western Delta during the spring. Numbers in parentheses are the number of tags returned in the second year on which the ratio is based. No corrections were made for variable exploitation rates, so ratios are biased estimates of survival.

tags have been out. Estimates are quite variable each calendar year, but there is no consistent trend of decreasing survival with increased time at large.

This finding and the fact that returns have been received through 8 years, indicate that shedding affects mortality estimates insignificantly.

Reporting of Tagged Fish

The striped bass fishery is so widespread that there is no practical way of assuring that anglers return all tags from fish they catch. Returns from the \$5 reward tags were compared with returns from comparable groups of nonreward tags to estimate the proportion of tags which were not returned.

This assumes that anglers return all \$5 reward tags. No check was made of this assumption. Undoubtedly some were not returned, causing nonresponse to be underestimated.

First-year returns of reward tags were significantly greater than the return of nonreward tags in all 4 years. However, except for the 1961 tags, differences were much smaller or nonexistent in subsequent years (Table 3).

TABLE 3
Comparison of Returns From Nonreward Tags and Different
Colors of Reward Tags

Year tagged	Tag description	Number tagged	Percentage returned each year					Total percentage returned
			1	2	3	4	5	
1958---	Nonreward-----	299	22.4	7.0	3.3	0.0	0.3	33.1
	White reward-----	150	40.0	6.7	2.7	1.3	1.3	52.0
1959---	Nonreward-----	1006	13.8	9.7	3.7	2.9	2.0	32.2
	White reward-----	125	23.2	11.2	2.4	0.8	1.6	39.2
	Orange reward-----	125	20.0	7.2	3.2	4.8	4.0	39.2
1960---	Nonreward-----	1587	14.2	7.6	4.4	4.0	1.8	31.9
	White reward-----	199	22.6	9.5	7.0	3.5	0.5	43.2
	Orange reward-----	201	17.9	13.4	5.0	2.5	2.0	40.8
1961---	Nonreward-----	995	10.6	9.2	7.6	2.7		30.2
	Orange reward-----	248	17.3	14.5	10.9	5.6		48.4

One factor undoubtedly contributing to this is that the red printing on the white reward tags faded. It sometimes became illegible after about a year, making the tags in effect nonreward tags. This led to the decision to use the orange reward tags. However, returns from these were generally lower than returns from the white tags, although differences were not significant (χ^2 for 1960 first-year returns = 1.37, $P = 0.24$).

Colors have been shown to influence tag returns (Lawler and Smith, 1963), and red tags have stimulated an antagonistic response in trout (German and LaFaucie, 1955). Thus, the orange tags may have influenced returns by some mechanism such as making bass more vulnerable to predation by sea lions.

While the cause for the smaller difference after the first year cannot be determined, it is not reasonable to attribute it to a true difference in nonresponse. Hence, only first-year returns were used in calculating nonresponse. Whatever caused the decreased nonresponse after the first year may well have commenced during the first year, causing nonresponse to be underestimated.

Calculated nonresponse varied considerably from year to year (Table 4). Since migration patterns varied annually (Chadwick, 1967), relationships between location of capture and nonresponse might explain this variation. Nonresponse tended to be lowest in San Pablo Bay and highest in the Pacific Ocean (Table 5). This appears reasonable since the San Pablo Bay fishery is the most concentrated and best covered by publicity, while the ocean fishery is the most widespread. However,

TABLE 4
Nonresponse During First Year After Tagging *

	Nonresponse	95 percent confidence limit for nonresponse	Number of reward tags	Number of nonreward tags
1958.....	0.470	0.3135-0.6263	135	277
1959.....	0.358	0.1630-0.5534	229	919
1960.....	0.311	0.1506-0.4708	381	1498
1961.....	0.389	0.1868-0.5906	239	950
Mean.....	0.385			

* Fish in poor condition when tagged were excluded.

TABLE 5
Nonresponse for Fish Recovered at Various Localities

Year tagged	Recovery localities			
	Delta	San Pablo Bay	San Francisco Bay	Pacific Ocean
1958.....	0.47	0.35	0.26	0.75
1959.....	0.20	0.37	0.40	0.75
1960.....	0.36	0.03	0.35	0.55
1961.....	0.30	-0.25	0.53	0.25
Weighted mean.....	0.33	0.13	0.39	0.58

annual variations from each locality were so large in relation to the differences among means that precise estimates are not possible. Hence nonresponse was assumed to be the same for all localities. If mean nonresponses for each area had been used, estimated exploitation rates would have been 4.5 to 7.8% lower.

The annual nonresponse estimates are subject to considerable chance variation (Table 4). Hence, the weighted mean nonresponse for the 4 years (0.385) was used for all years.

Representativeness of Sample

The sample of bass tagged in the western Delta during the spring does not include immature females, since they do not migrate to the Delta. In addition, males and larger bass may be overrepresented, the former because males remain on the spawning grounds longer than females; the latter because the fishing gear and methods used are selective for larger fish (Chadwick, 1967).

Other than this, the representativeness of the sample may be judged only by comparing results among different segments of the sample and between the main sample and samples taken from other segments of the population.

Percentage returns from bass tagged in the western Delta at different times during the spring and at different locations there do not differ significantly (Tables 6 and 7). These groups also have similar migra-

tion patterns (Chadwick, 1967), so that any failure of the sample to be random in these respects would not bias results.

TABLE 6
Relationship Between Time of Tagging and Percentage of Tags
Returned During First Year *

Relative time of tagging	Year tagged			
	1958	1959	1960	1961
Early-----	22.3 (4/11-4/30)	13.2 (4/6 -5/7)	14.2 (4/6 -5/10)	12.6 (4/8 -4/25)
Midseason-----	23.0 (4/28-5/8)	16.2 (5/7 -5/20)	16.4 (5/9 -5/18)	11.0 (4/25-5/23)
Late-----	22.4 (5/8 -6/4)	15.8 (5/21-6/11)	12.3 (5/18-6/2)	

* Tagging dates are indicated in parentheses. Includes only fish in good condition tagged in the western Delta.

TABLE 7
Relationship Between Location of Tagging in the Western Delta
and Percentage of Tags Returned During First Year *

Tagging location	Year tagged			
	1958	1959	1960	1961
Broad Slough (D)-----	21.3 (461)	14.7 (129)	15.3 (340)	
Chain Island (B)-----	24.1 (1293)	15.7 (236)	14.0 (473)	
False River (E)-----	19.4 (599)	14.0 (1204)	13.0 (1326)	11.3 (1182)
Sherman Island (C)-----	24.3 (1538)	16.0 (1305)	16.2 (1219)	11.9 (404)
Chippis Island (A)-----		15.4 (91)		

* Fish in poor condition when tagged are excluded. Numbers of tagged fish listed in parentheses. Letters in parentheses after tagging locations refer to locations in Figure 1.

Of the 889 bass tagged at Fremont Weir on the upper Sacramento River, 28.3% were returned the first year. Only 23.1% of the comparable group of 3,891 bass from the western Delta were returned the first year. These percentages differ significantly ($\chi^2 = 10.99$, $P < 0.001$). However, the April through February returns during the first year (20.4 and 21.2%, respectively) do not differ significantly. Migrations of the two groups showed an analogous difference, because most Fremont Weir fish return to the upper Sacramento River during the spring (Chadwick, 1967). This indicates that the difference in percentage returns is caused by most Fremont Weir fish being subjected to the intensive fishery in the Sacramento River.

Hence, mortality estimates would be biased by inadequate representation of upper Sacramento River fish in the sample. While many

bass tagged in the western Delta migrated up the Sacramento River, this group is probably inadequately represented, because many bass migrate up the river before tagging began each spring. This probably causes returns from the Delta sample to underestimate fishing mortality slightly.

Of the 886 bass in good condition tagged at Prisoners Point in the eastern San Joaquin Delta in 1959, 14.6% were returned. Returns from a comparable group of 2,965 bass tagged in the western Delta were 15.1%—a nonsignificant difference. Thus, the rate of return from the western Delta sample is representative of the rate among bass migrating to the eastern Delta.

In summary, each of the factors affecting the validity of mortality estimates—immediate tagging mortality, biases in nonresponse, decreased vulnerability, and underrepresentation of the Sacramento River run—causes small errors. Assuming that nonresponse is underestimated due to downward biases exceeding the possible upward bias associated with not stratifying estimates by area, all four errors cause fishing mortality to be underestimated.

The first two cause natural mortality to be overestimated, while the second two cause survival to be overestimated.

MORTALITY ESTIMATES

Spring Tagging

The number of usable nonreward disk dangler tags ranged from 3,891 to 1,609, and returns have been received regularly from all groups through May 1967 (Table 8).

TABLE 8
Summary of Spring Tagging in the Western Delta

Year tagged	Number tagged*	Number of annual returns†								
		1958-9	1959-60	1960-1	1961-2	1962-3	1963-4	1964-5	1965-6	1966-7
1958.....	3,891	890	207	103	52	27	14	12	7	8
1959.....	2,965		450	266	111	89	61	20	12	17
1960.....	3,358			503	261	158	145	59	35	33
1961.....	1,609				188	131	117	53	21	25
Totals.....	11,823				612	405	337	144	75	83

* Includes only nonreward tags which were in good condition after tagging.

† Numbers are not corrected for nonresponse.

The estimated rate of exploitation and expectation of deaths from natural causes were 50% higher in 1958 than in any of the next 6 years (Table 9). During that 6-year period, the rate of exploitation fluctuated from approximately 0.28 to 0.19, while survival rates varied from 0.51 to 0.66. No estimates are included for 1965-66 and 1966-67 because few returns were received, and tagging during 1965 and 1966 (Inland Fisheries Branch, unpubl. data) will provide more accurate estimates of mortality rates in these years. The 1966-67 returns are of particular interest because they exceed the 1965-66 returns. Returns

from the fish tagged in 1965 show a similar trend (Lee W. Miller, pers. comm.), presumably indicating a substantial increase in the rate of exploitation in 1966-67.

TABLE 9
Mortality Rate Estimates *

	Survival rate	Rate of exploitation	Expectation of death from natural causes	Instantaneous total mortality rate	Instantaneous fishing mortality rate	Instantaneous natural mortality rate
1958.....	0.319	0.372	0.309	1.14	0.62	0.52
1959.....	0.534	0.247	0.219	0.63	0.33	0.30
1960.....	0.601	0.243	0.156	0.51	0.31	0.20
1961.....	0.662	0.190	0.118	0.41	0.23	0.18
1962.....	0.592	0.200	0.208	0.52	0.25	0.27
1963.....	0.511	0.281	0.208	0.67	0.39	0.28
1964.....	0.557	0.235	0.208	0.67	0.36	0.31

* Includes only striped bass tagged in the western Delta during the springs of 1958 through 1961. Estimates below line are approximations based on the assumption that ratio of 1962 to 1961 returns is a valid estimate of 1961 survival, and that the annual expectation of death from natural causes from 1962 through 1964 was equal to the 1958 through 1961 mean.

Estimated variances of survival rates (equation 9) were 0.000275, 0.000516, and 0.000787, respectively, in 1958, 1959, and 1960. Thus, survival was significantly lower (95% confidence level) in 1958 than in 1959 or 1960, but it did not differ significantly in 1959 and 1960. The respective proportions of each year's tags which were returned during the first year after tagging and their 95% confidence intervals (estimated using equation 5) were 0.229 ± 0.013 , 0.152 ± 0.013 , 0.150 ± 0.012 , and 0.117 ± 0.016 . Thus, 1958 returns were significantly greater than, and the 1961 returns were significantly lower than, the 1959 and 1960 returns.

The 95% confidence limits (from equation 6) for the 1959 through 1961 rate of exploitation were 0.372 ± 0.058 , 0.247 ± 0.042 , 0.243 ± 0.041 , and 0.190 ± 0.038 . Thus, the 1958 rate was significantly higher than the rate in any subsequent year. While the 1961 estimate was not significantly lower than the 1959 and 1960 estimates, the significant differences in the proportion of tags actually returned in these years indicate that the differences in rates of exploitation were probably real.

Rate of exploitation increased linearly with fish length in 1958 and 1960, but no similar relationship existed in 1959 and 1961 (Table 10). The relationship was much more pronounced in 1958 than in 1960 and was due largely to the unusual catch of large bass in the Pacific Ocean that summer (Chadwick, 1967). If bass caught in the ocean are eliminated from the tag returns, the respective percentage returns for the 15-17, 18-19, 20-21, 22-23, 24-26, 27-29, and 30-plus-inch length groups become 16.9, 19.0, 21.1, 20.2, 21.5, 21.9, and 26.9.

TABLE 10
Relationship Between Length at Tagging and First Year Returns *

Fork length in inches	Percentage returns from each year's tags			
	1958	1959	1960	1961
15-17.....	17.2	15.3	11.3	7.6
18-19.....	19.9	10.3	12.5	13.5
20-21.....	22.2	16.6	14.8	14.8
22-23.....	22.5	15.8	13.9	10.9
24-26.....	25.6	16.5	15.2	10.0
27-29.....	28.8	13.7	19.1	12.1
30+.....	36.5	16.9	14.5	14.5
Overall χ^2 value†.....	<0.001	0.08	0.19	0.34
χ^2 due to linear regression.....	<0.001	0.12	0.02	>0.90

* Results include only nonreward disk dangler tags from fish in good condition when tagged.

† Data analyzed with chi-square test with overall chi-square value subdivided to identify portion due to linear trend (Maxwell, 1961, p. 63-69). Values listed are probabilities of getting a larger χ^2 value by chance.

In 1960, 13.6% of the 2,472 tags on male bass were returned during the first year, while 17.3% of the 886 tags on females were returned. This difference is significant ($\chi^2 = 7.2$, $P < 0.01$). The comparable percentages in 1961 (11.0% from 1,036 males and 12.6 from 573 females) did not differ significantly ($\chi^2 = 0.89$, $P = 0.37$).

In 1961, tags from 192 of the males and 74 of the females tagged in 1960 were returned. Assuming that survival was not constant in 1960 and 1961, survival of males and females in 1960 would have been 0.706 and 0.665, respectively.

Survival in 1961 can be estimated only by assuming equal survival in 1960 and 1961. Estimates for males and females would be 0.614 and 0.847, respectively. The latter indicates an expectation of death from natural causes of 0.027, which is unreasonably low. This probably reflects chance variability associated with the relatively small sample size.

While this evidence is limited, it suggests that mature males have a lower rate of exploitation and higher survival than females.

Fall Tagging

Delta

Of the 628 bass tagged in the western Delta during the fall of 1958, 128 were returned during the first year. Assuming a nonresponse of 0.385, the rate of exploitation was 0.33. This is intermediate between the rates of exploitation estimated for bass tagged in the springs of 1958 and 1959.

In order to compare the timing of mortality in spring- and fall-tagged fish, the number of bass tagged in the spring of 1958 which were alive at the end of November 1958 was estimated. This was done by dividing the number of tag returns caught through November 30 by the number caught during the year to estimate the fraction of the annual exploitation rate occurring between the spring and November 30. An equal fraction of annual deaths from natural causes was assumed to have occurred during this period.

From December 1958 through December 1959, the fraction of tags actually returned from the 1958 spring and fall tagging (Table 11) did not differ significantly ($\chi^2 = 2.50$, $P = 0.12$). This fact and the fall returns being intermediate between returns from the two springs indicate that angling and natural mortality occur at roughly proportional rates within the year. This is necessary if instantaneous mortality rates are to be estimated accurately from tag returns.

TABLE 11
Seasonal Occurrence of Angling Mortality From December 1958 through December 1959 for Three Groups of Tagged Bass *

Month of recovery	Spring 1958 Delta tags	Fall 1958 Delta tags	Fall 1958 San Pablo tags
Dec.-Feb.	0.048	0.040	0.050
Mar.-May.	0.067	0.100	0.128
June-Sept.	0.048	0.037	0.056
Oct.-Dec.	0.029	0.043	0.073
Total.	0.191	0.220	0.307
Estimated number alive at beginning of period.	2175	628	673

* Expressed as the fraction of those estimated to be alive on December 1, 1958, which were returned during given periods.

San Pablo Bay

Assuming a nonresponse of 0.385 first-year rate of exploitation estimates for bass tagged in San Pablo Bay in the falls of 1958 and 1959 were 0.551 and 0.572, respectively.⁵ Assuming constant survival, 1958 survival and expectation of deaths from natural causes was 0.303 and 0.146, respectively. Hence, the primary difference between the Delta and San Pablo Bay groups is in the considerably higher rate of exploitation in the latter. This difference resulted largely from high returns from San Pablo Bay tags in the spring and fall (Table 11).

DISCUSSION

Variations in Mortality Rates

Returns from the spring and fall 1958 Delta tagging indicate that fishing and natural mortality occur at nearly proportional rates within the year, so instantaneous and annual mortality rates can be calculated from annual expectations of death. These estimates are included in Table 9.

The higher rates of exploitation among San Pablo Bay fish are probably a function of migration differences. A higher fraction of fish tagged in San Pablo Bay than those tagged in the Delta remains in San Francisco and San Pablo Bays during the winter and spring (Chadwick, 1967). This presumably reflects the failure of legal-sized immature bass, which are primarily females, to participate in the spawning migration to the Delta. The high spring returns from San Pablo Bay fish probably reflect greater vulnerability of immature fish during the

⁵ Actual first-year returns were 254 of 750 for 1958 tags and 38 of 108 for 1959 tags. Second-year returns from 1958 tags totaled 77.

spawning period since mature bass eat little then (Stevens, 1967; Thomas, 1967). Hence, immature fish in the Bay Area are exploited more heavily than the mature fish are.

In the 4 years when both the rate of exploitation and expectation of deaths from natural causes were estimated, they were positively correlated (Table 9). While the sample is small, it suggests that either fishing contributes to "natural" mortality, through a factor such as deaths from hooking, or some fishing deaths were erroneously attributed to natural mortality. The most probable cause of the latter is underestimated nonresponse. These hypotheses cannot be evaluated with available data but both probably contribute.

One of this study's most significant findings is the magnitude of fluctuations in the rate of exploitation. As pointed out earlier, the homogeneity, both in terms of geographical and seasonal migration patterns (Chadwick, 1967) and in terms of the proportions returned from different groups of tags applied in any given year, is strong evidence of the validity of this conclusion. The most probable cause for these variations in exploitation rates is annual variations in catchability.⁶ Both annual variations in migrations and changes in angling efficiency related to weather and water conditions undoubtedly changed catchability. However, sufficient facts are not available to explain the specific changes observed in exploitation rates.

Variations of this magnitude in exploitation rates would cause considerable variations in total catch and catch per unit of effort, independent of changes caused by variations in population size. Thus, wide variations in total catch and catch per unit of effort which parallel changes in exploitation rates would support the validity of the exploitation rates.

Only crude estimates of trends in total catch and effort (Seeley, Tharratt, and Johnson, 1963; Albrecht, 1964) and more precise catch-per-unit-of-effort measurements for a few segments of the fishery (Chadwick, 1962; L. W. Miller and R. J. McKechnie, MS; R. J. McKechnie, MS) are available for the period covered by this tagging study. The latter provide evidence of wide fluctuations in catchability in segments of the fishery, but neither source provides evidence of overall trends paralleling indicated fluctuations in exploitation rates. The significance of this is difficult to interpret because of imperfections in all measurements. This emphasizes the need for better measurements of catch and effort.

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⁶ Catchability is defined as the fraction of the whole fish stock which is caught by a unit of fishing effort. It reflects the efficiency of fishing techniques (vulnerability) and the distribution of the population in respect to fishing effort (availability) (Ricker, 1958).

analytical procedures. Formulas 6, 7, and 8 were derived in essentially their present form by Dr. Paulik.

The program could not have succeeded without the support of the Boards of Supervisors of Contra Costa and Alameda Counties. These boards appropriated county funds to reimburse anglers returning reward tags.

I also wish to thank the thousands of cooperative California anglers who returned tags.

SUMMARY

Mortality rates in the striped bass population inhabiting the Sacramento-San Joaquin river system were calculated from returns of 11,823 disk dangler tags. Fish were tagged in the Delta each spring from 1958 through 1961. Returns from these tags were corrected for nonresponse based on the return of \$5 reward tags.

Analysis of those returns and returns from bass tagged at other places in the river system indicate that tag returns gave reasonably valid estimates of mortality rates, although rates of exploitation are probably underestimated.

The rate of exploitation ranged from 0.372 in 1958 to 0.190 in 1961. Survival ranged from 0.319 in 1958 to 0.662 in 1962. These variations probably reflect differences in catchability due to variations in migrations and angling efficiency. Bass tagged in San Pablo Bay had a considerably higher rate of exploitation, probably reflecting the different migration pattern of immature legal-sized bass.

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SOME ENDOPARASITES OF FISHES FROM THE SACRAMENTO-SAN JOAQUIN DELTA, CALIFORNIA¹

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A survey of 236 fishes representing 26 species in fresh waters of the Sacramento-San Joaquin Delta revealed the presence of a number of helminths. The present paper discusses or describes the following species. Trematoda: *Posthodiplostomum minimum centrarchi* (MacCallum, 1921; Dubois, 1936) Hoffman, 1958 from *Archoplites interruptus* (Girard), *Chaenobryttus gulosus* Cuvier, *Lepomis cyanellus* Rafinesque, and *L. macrochirus* Rafinesque; *Neascus* sp. from *Hysteroecarpus traski* = *traskii*; *Neascus* sp. from *Lepomis cyanellus*; *Pisciamphistoma stunkardi* (Holl, 1929) Yamaguti, 1934 from *Chaenobryttus gulosus* and *Lepomis gibbosus* Linnaeus; *Alloglossidium corti* (Lamont, 1921) Mueller, 1930 from *Ictalurus catus* (Linnaeus) and *Lepocreadium californianum* sp. n. from *Roccus saxatilis* (Walbaum). Cestoda: *Corallobothrium giganteum* Essex, 1927 from *Ictalurus catus*; *C. fimbriatum* Essex, 1927 from *Ictalurus catus* and *I. punctatus* Rafinesque, *Proteocephalus* sp. from *Ictalurus catus*; *Bothriocephalus* sp. from *Chaenobryttus gulosus* and *Lepomis cyanellus*; *Pelichnibothrium* sp. from *Salmo gairdnerii* Richardson. Acanthocephala: *Rhadiorhynchus* sp. from *Salmo gairdnerii*.

A key to 23 species in the genus *Lepocreadium* is given.

INTRODUCTION

To date there has been only one major study concerned with endoparasites of freshwater fishes of California. Haderlie (1953) summarized investigations up to that year and conducted a general survey of the monogenetic and digenetic trematodes, cestodes, nematodes, acanthocephalans, copepods, and hirudinians of fishes of northern California. From 2,010 fishes representing 36 species in 11 families, examined over a three-year period, he obtained a total of 59 species of helminths, copepods, and hirudinians.

Other investigations include those of Wales (1958), who described two new blood flukes, one infecting trout in southern Oregon, the other common in northern California hatcheries and rivers. Colley and Olsen (1963) studied the metacercaria of *Posthodiplostomum minimum* (MacCallum, 1921) Dubois, 1936 in fishes of Lower Otay Reservoir, San Diego County.

The primary purpose of the current investigation was to gain some knowledge of the species of endoparasites of fishes of the Sacramento-San Joaquin Delta. Two hundred and thirty-six fishes representing 26 species were examined between March 1966 and June 1967. This has resulted in the recovery of three metacercariae, three adult digenea, several adult, immature and larval cestodes, one acanthocephalan, and

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several species of nematodes. Not included in this paper are the nematodes and the caryophyllacid cestodes; the latter group is represented by poorly processed specimens.

The major site of collection was the fish collecting facility of the U. S. Bureau of Reclamation at its Tracy Pumping Plant. Other collecting sites included various locations in Middle, Old, Sacramento, San Joaquin, and Calaveras Rivers in the Delta.

Trematodes and small cestodes were fixed in alcohol-formalin-acetic acid (AFA) under slight cover slip pressure. Large cestodes were allowed to relax and extend in chloretone or in the refrigerator for several hours before AFA fixation. The single acanthocephalan was placed in fresh water in the refrigerator overnight until the proboscis became fully extended. All worms were stained with Semichon's carmine, dehydrated in successive and increasing concentrations of alcohol, cleared in methyl salicylate, and mounted in Kleermount.

All drawings and their scales were made by microprojection, with details filled in from microscopic examination. Measurements are in mm except for eggs, which are given in μ . Sucker ratios for trematodes were calculated by taking the average of the length and width of each, the oral sucker being expressed as one. A new host record is indicated by an asterisk.

PHYLUM PLATYHELMINTHES

Class Trematoda

Posthodiplostomum minimum centrarchi (MacCallum, 1921; Dubois, 1936) Hoffman, 1958

Hosts: **Archoplites interruptus* (Girard)

Chacnobryttus gulosus Cuvier

Lepomis cyanellus Rafinesque

Lepomis macrochirus Rafinesque

Site: Encysted in the liver and on the heart

Ncascus sp.

Figure 1A

Host: *Hysteroecarpus traski i-traskii* Gibbons

Site: Encysted on the heart

These metacercariae are described separately because of the possibility that they may represent a new species. The host is a member of the family Embiotocidae, which is not known to harbor the metacercaria of *Posthodiplostomum minimum*. A certain host specificity is believed to exist in this group of larval trematodes (Miller, 1953; Hoffman, 1960, 1967). Measurements based on a typical worm: body elongate; forebody 1.200 long by 0.480 wide; hindbody 0.480 long by 0.360 wide. Oral sucker 0.053 in diameter, terminal; pharynx 0.044 long by 0.031 wide; ventral sucker equatorial with respect to total body length, 0.077 long by 0.083 wide; holdfast organ considerably posterior to ventral sucker, 0.181 long by 0.165 wide; holdfast gland distinct, at posterior border of holdfast organ. Cecae extend past primordial gonads in hindbody. Gonadal primordia confined to central

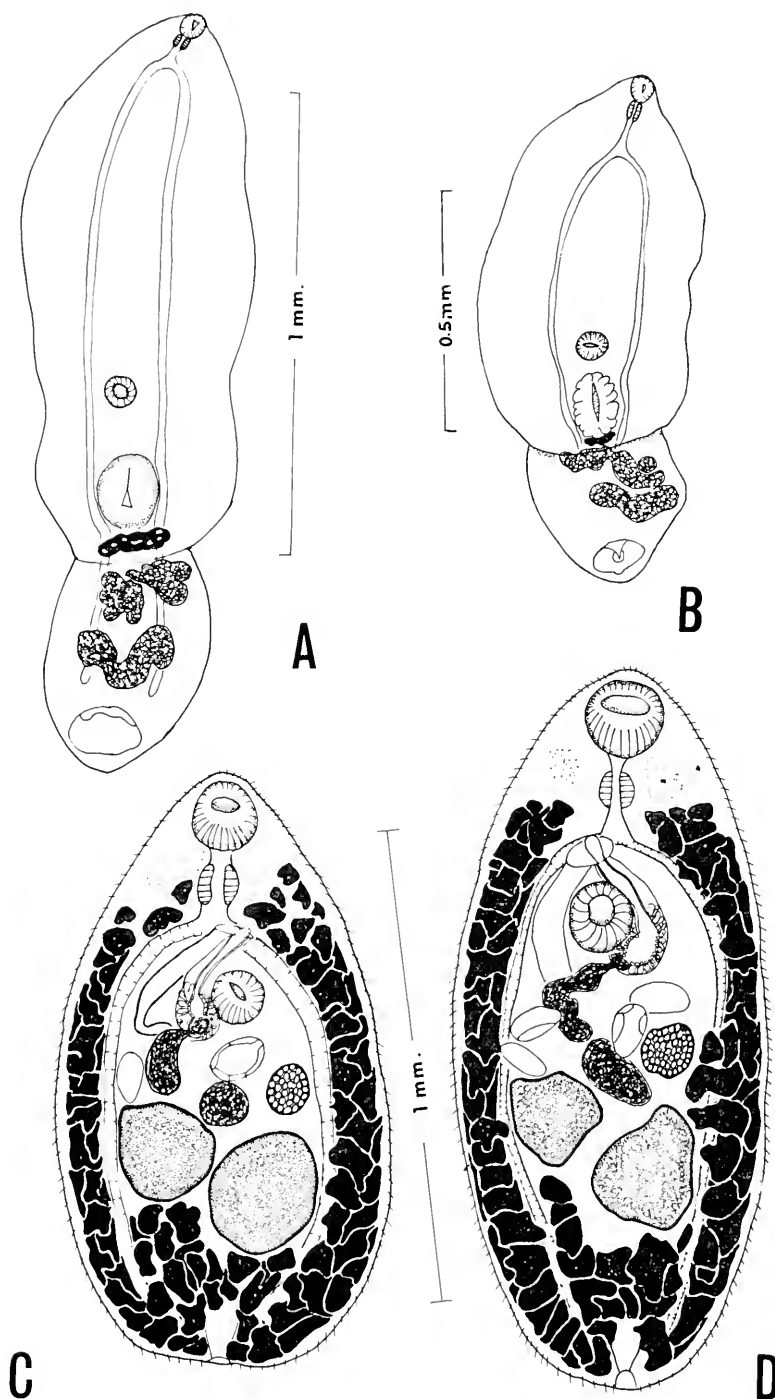


FIGURE 1—A, *Neascus* sp. from *Hysterocarpus traski* \equiv *traskii* Gibbans, ventral view; B, *Neascus* sp. from *Lepomis cyanellus* Rafinesque, ventral view; *Lepochradium californianum* sp. n., paratype, ventral view; D, *L. californianum* sp. n. from *Roccus saxatilis* (Walbaum), holotype, ventral view.

region of the hindbody; bursa copulatrix subterminal, 0.107 long by 0.165 wide. Reserve bladder throughout forebody, branching and anastomosing.

Neosculus sp.

Figure 1B

Host: *Lepomis cyanellus* Rafinesque

Site: Unencysted in the vitreous humor of the eye

In one green sunfish, metacercariae were found unencysted in the eye. Due to the unique site of the infection, and the morphological variation in the holdfast gland and holdfast organ, it is believed that this worm may represent a species different from those given earlier. Description and measurements based on one typical specimen: body spatulate, 1.080 long; forebody 0.816 long by 0.445 wide; hindbody 0.264 long by 0.354 wide. Oral sucker subterminal, 0.044 long by 0.048 wide; pharynx 0.036 long; ventral sucker equatorial with respect to total body length, 0.060 long by 0.067 wide; holdfast organ with serrated margin, 0.132 long by 0.107 wide; holdfast gland indistinct at posterior border of holdfast organ. Ceca extend to level of constriction. Gonadal primordia confined to hindbody; bursa copulatrix oval, subterminal, 0.071 long by 0.108 wide. Reserve bladder confined to forebody, composed of branching and anastomosing tubules.

Pisciamphistoma stunkardi (Holl, 1929) Yamaguti, 1954

Synonym: *Paramphistomum stunkardi* Holl, 1929

Hosts: *Chacnobryttus gulosus* Cuvier
Lepomis gibbosus Linnaeus

Site: Posterior region of intestine

Deposited specimen: U.S. National Museum No. 70959

This species was first described by Holl (1929) as *Paramphistomum stunkardi*. Yamaguti (1954) placed this species in the genus *Pisciamphistoma*, which he distinguished from *Paramphistomum* by the presence of an esophageal bulb. In his original description, Holl (1929) reports finding it in the pumpkinseed, *Lepomis gibbosus*, and in the warmouth, *Chacnobryttus gulosus*, in Durham, North Carolina. Bangham (1940, 1941) and Bangham and Venard (1942) reported a very low rate of infection by this worm in centrarchid and silurid fishes of Florida, Ohio, and Tennessee. Haderlie (1950, 1953) found it in 4 out of 69 black crappie, *Pomoxis nigromaculatus*. It is of interest to note that our material was also found in the pumpkinseed and warmouth, the hosts from which *Pisciamphistoma stunkardi* was originally recovered. Both fishes were introduced into California from the eastern United States.

Alloglossidium corti (Lamont, 1921) Mueller, 1930

Synonyms: *Plagiorchis corti* Lamont, 1921

Plagiorchis amciurensis McCoy, 1928

Alloglossidium kenti Simer, 1929

Host: *Ictalurus catus* (Linneaus)

Site: Posterior region of intestine

Deposited specimen: U.S. National Museum No. 70960

Six specimens were recovered from the above host and are referred to this species on the basis of topography of gonads, extent of vitellaria, cirrus sac, and uterus. These specimens, however, are somewhat larger (1.70–2.00 x 0.370–0.430), the eggs a little wider (28–36 x 15–21 μ), and perhaps of greater significance is the indistinct lobation on the anterior margin of the pharynx, observed in all specimens.

Lepoercadium californianum sp. n.

Figures 1C, 1D

Host: *Roccus saratilis* (Walbaum)

Site: Intestine

Holotype: U.S. National Museum No. 70961

Description (based on three specimens, one sectioned frontally): body oval to pyriform, 1.248–1.536 long by 0.576–0.648 wide at the level of the ventral sucker. Cuticular spines extending to posterior end of body. Eye spot pigments present. Oral sucker 0.156–0.173 long by 0.165 wide, subterminal; ventral sucker at posterior end of anterior third of body, 0.115–0.119 in diameter; sucker ratio 1:0.70–0.72. Prepharynx 0.027–0.040 long; pharynx 0.065–0.083 long by 0.073–0.081 wide; esophagus 0.042–0.071 long; ceca narrow, long, extending to posterior end of body.

Testes two, oblique, triangular to irregular in outline; anterior testis right of midline in posterior half of body, 0.165–0.206 long by 0.198–0.239 wide; posterior testis 0.198–0.272 long by 0.198–0.247 wide; cirrus sac well developed, extending left of acetabulum in two specimens, right in the third, slightly posterior to ventral sucker, enclosing spherical internal seminal vesicle 0.038–0.066 long by 0.036–0.041 wide, well-developed prostate vesicle, prostate glands, and muscular cirrus 0.206–0.263 long; external seminal vesicle saccate to tubular 0.123–0.222 long by 0.049–0.066 wide.

Ovary pretesticular, equatorial to left of midline, 0.082–0.107 long by 0.091–0.132 wide, margin entire or slightly irregular; seminal receptacle spherical to ovoid, 0.090–0.156 long by 0.041–0.107 wide; uterus short, pretesticular; metraterm well developed to right of ventral sucker. Genital pore median or submedian at level of intestinal bifurcation. Eggs few, maximum number four; opaque ones 112–128 by 51–72 μ .

Vitelline follicles large, mostly extraeceal, extending from level of pharynx to posterior end of body, confluent posterior to testes. Excretory vesicle tubular, extending to anterior margin of left testis; pore terminal.

Lepoercadium californianum sp. n. is to be compared with and distinguished from those species of *Lepoercadium* with large eggs. These include *L. archosargi* Pearse, 1949 (eggs 140 x 60), *L. micropogoni* Pearse, 1949 (eggs 130 x 60), and *L. caballeroi* Sogandares-Bernal and Hutton, 1960 (eggs 108–112 x 48). *L. ovale* Manter, 1931, *L. seti-*

feroides Martin, 1938, *L. trullaforme* Linton, 1940, and *L. elongatum* (Nagaty, 1942) also have large eggs, though somewhat smaller than those of the first three species.

Lepoercadium californianum sp. n. differs from all of the above-mentioned species in the reversed position of the gonads. The ovary is sinistral and close to the left cecum, and the right, rather than the left, testis is more anterior. From *L. archosargi* it differs in lacking two ani; the vitellaria extend less anteriorly; there is a smaller ratio of egg length to ventral sucker diameter; and a greater posterior extent of spination. *L. micropogoni* was considered species inquerenda by Sogandares-Bernal and Hutton (1960). Pearse's drawing (Pearse, 1949) shows a small cirrus sac, mostly preacetabular. Other distinguishing features include a less posterior extension of spines and a greater egg length-ventral sucker ratio in *L. micropogoni*. From *L. caballeroi*, *L. californianum* sp. n. differs in body shape, greater anterior extent of vitellaria, and in having an entire rather than a bilobed ovary; from *L. orale* in having larger but fewer eggs; from *L. scitiferoides* in body shape and better-developed prostate complex; from *L. trullaforme* in having more oblique testes, fewer and larger eggs, and in lacking confluent vitellaria dorsal to the intestinal bifurcation; from *L. elongatum* in body shape, lesser posterior extent of the cirrus sac, more tubular external seminal vesicle, and in having an entire rather than a four or five lobed ovary.

Lepoercadium californianum sp. n. is the first member in this genus to be reported from a fish in fresh water. The host, a striped bass, *Roccus saxatilis*, was obtained from the Tracy fish collecting facility. The water in this area is characterized as fresh according to the 1958 Venice Hydrobiological Nomenclature. The host, 5 inches in length, was approximately 1 year old. A fish of this size could have migrated to the Tracy fish collecting facility from a downstream marine environment.

Manter (1962, 1963), in discussing zoogeographical relationships of trematodes, indicates that members of the family Lepoercadiidae are primarily parasites of marine fishes, the Homalometroninae being the only subfamily with members parasitizing fishes in salt, brackish, and freshwater environments. In the latter paper Manter states "freshwater fishes with parasites of this subfamily usually have marine connections of some kind".

The genus *Lepoercadium* is a member of the subfamily Lepoercadiinae, members of which are strictly marine. Therefore, recovery of *L. californianum* sp. n. from a fish in a freshwater environment was unexpected. In all likelihood this was a recent infection in the host during a temporary residence in a marine environment.

Of the 31 species placed to date in the genus *Lepoercadium*, the authors recognize 24 species as valid members of the genus; twenty-three species including *L. californianum* sp. n. are compared in the following key and one, *L. pycgorchis* (Stossich, 1901) Stossich, 1903, is not included because its description is not available to us. The other seven species should be retained as members of the closely related genera *Lepidapedon*, *Opechona*, and *Pseudoercadium*.

Key to the Species of *Lepocreadium* Stossich, 1903

- 1a. Vitellaria extend anteriorly to level of ventral sucker or below;
testes tandem ----- 2
- 1b. Vitellaria extend to intestinal bifurcation or more anteriorly;
testes tandem or oblique ----- 4
 - 2a. Body elongate; ovary entire ----- 3
 - 2b. Body pyriform; ovary lobed -----
 - *L. truncatum* Nahhas and Cable, 1964
- 3a. Cirrus spiny; cirrus sac extends posterior to ventral sucker, almost
half way to ovary ----- *L. pyriforme* (Linton, 1900) Linton, 1940
- 3b. Cirrus not spiny; cirrus sac does not extend posterior to ventral
sucker ----- *L. bimarimum*, Manter, 1940
 - 4a. Eggs as large as or larger than diameter of ventral sucker 5
 - 4b. Eggs smaller than diameter of ventral sucker ----- 9
- 5a. Testes tandem; eggs small, 45–55 x 30–37 μ -----
 - *L. hemiramphi* Nahhas and Cable, 1964
- 5b. Testes oblique; eggs large, usually more than 100 μ in length 6
 - 6a. Right testis anterior ----- *L. californianum* sp. n.
 - 6b. Left testis anterior ----- 7
- 7a. Ani (2) present; vitellaria extend anteriorly to level of oral sucker
----- *L. archosargi*, Pearse, 1949
- 7b. Ani absent; vitellaria do not reach oral sucker ----- 8
 - 8a. Vitellaria extend anteriorly to level of pharynx; cirrus sac
does not extend posterior to midacetabular level -----
 - *L. micropogoni* Pearse, 1949
 - 8b. Vitellaria extend anteriorly to cecal bifurcation; cirrus sac
extends half way between acetabulum and anterior testis ---
 - *L. caballeroi* Sogandares-Bernal and Hutton, 1960
 - 8c. Vitellaria to pharyngeal level; cirrus sac extends slightly
posterior to acetabulum ----- *L. setiferoides* Martin, 1938
- 9a. Ovary entire ----- 10
- 9b. Ovary lobed ----- 13
 - 10a. Testes tandem, lobed -----
 - *L. album* (Stossich, 1890) Stossich, 1903
 - 10b. Testes tandem, entire ----- *L. bravoae* Lamothe, 1964
 - 10c. Testes oblique, smooth ----- 11
- 11a. Vitellaria confluent dorsally at level of intestinal bifurcation and
posterior testis; eggs 84–88 x 40–44 -----
 - *L. trullaforme* Linton, 1940
- 11b. Vitellaria not confluent as above ----- 12
 - 12a. Eggs 96 x 56 ----- *L. ovale* Manter, 1931
 - 12b. Eggs 54–72 x 33–38 -----
 - *L. opsauusi* Sogandares-Bernal and Hutton, 1930
- 13a. Cirrus sac does not extend posterior to ventral sucker ----- 14
- 13b. Cirrus sac extends posteriorly some distance between ventral
sucker and gonads ----- 18
 - 14a. Pharynx with lobed anterior border ----- 15
 - 14b. Pharynx simple ----- 16

- 15a. Body oval; testes entire; external seminal vesicle rudimentary
----- *L. exiguum* Manter, 1963
- 15b. Body truncate posteriorly; testes deeply lobed; external seminal
vesicle long and narrow ----- *L. incisum* Hanson, 1955
- 16a. Vitellaria extend anteriorly to and overlapping oral sucker;
pharynx smaller than ventral sucker; external seminal vesicle
small and spherical ----- *L. vitellosum* (Ozaki, 1936) Manter, 1946
- 16b. Vitellaria extend anteriorly to level of pharynx; pharynx
about same size as ventral sucker or slightly larger; external
seminal vesicle elongate ----- 17
- 17a. Body truncate posteriorly; genital pore to right of midline, near
the posterior border of the pharynx ----- *L. maris* (Caballero, 1957) Manter, 1963
- 17b. Body oval to elongate; genital pore just behind intestinal bifur-
cation, somewhat sinistral to midline ----- *L. clavatum* (Ozaki, 1932) Yamaguti, 1938
- 18a. Testes tandem ----- 19
- 18b. Testes oblique ----- 20
- 19a. Pharynx massive, larger than ventral sucker; cirrus spiny ----- *L. brevoortiae* Nahhas and Short, 1965
- 19b. Pharynx smaller than ventral sucker; cirrus not spiny ----- *L. floridanum* Sogandares-Bernal and Hutton, 1959
- 20a. Body truncate posteriorly; ovary three-lobed; external semi-
nal vesicle tubular or elongate; genital pore median or sub-
median, near intestinal bifurcation ----- *L. trulla* (Linton, 1907) Linton, 1910
- 20b. Body elongate; ovary four- or five-lobed; external seminal
vesicle spherical or ovoid; genital pore midway between
acetabulum and intestinal bifurcation, sinistral ----- *L. elongatum* (Nagati, 1942) Manter, 1946

Class Cestoda

Corallobothrium giganteum Essex, 1927

Host: *Ictalurus catus* (Linnaeus)

Site: Intestine

Corallobothrium fimbriatum Essex, 1927

Hosts: *Ictalurus catus* (Linnaeus)

I. punctatus Rafinesque

Site: Anterior third of intestine

Proteocephalus sp.

Host: *Ictalurus catus* (Linnaeus)

Site: Intestine

Eight larval and immature proteocephalids were recovered. These cestodes possess four simple suckers but no apical organ is evident.

Two other larval proteocephalids were found in the liver of *Lepomis gibbosus* Linnaeus. The scolex possesses four simple suckers and a non-muscular apical organ.

Bothriocephalus sp.

Hosts: *Chacnobryttus gulosus* Cuvier
Lepomis cyaneus Rafinesque

Site: Intestine

Four immature worms were collected. Members of this genus possess a characteristic scolex composed of two longitudinally elongated bothria and apical disc having indented edges.

Pclichnibothrium sp.

Host: *Salmo gairdnerii* Richardson

Site: Intestine

Identification of the three larval tapeworms is based on the presence of four nonserrated sessile bothridia, each terminating anteriorly in an accessory sucker, and a fifth apical sucker. The latter characteristic distinguishes this genus from *Phyllobothrium*. Haderlie (1953) erroneously placed similar larvae obtained from *Oncorhynchus tshawytscha* in *Phyllobothrium*, but his drawings and description clearly indicate the presence of a fifth apical sucker.

PHYLUM ACANTHOCEPHALA

Rhadinorhynchus sp.

Host: *Salmo gairdnerii* Richardson

Site: Intestine

A single female specimen was found and is referred to this genus on the basis of trunk spination. Members of this genus are characteristically marine. Shaw (1947) reported *Rhadinorhynchus* sp. from the same host in Oregon.

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A PROBABILITY SEA SURVEY PLAN FOR ESTIMATING RELATIVE ABUNDANCE OF OCEAN SHRIMP¹

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A stratified two-stage research vessel survey was designed to estimate the relative abundance of ocean shrimp, *Pandalus jordani*, in the Klamath River-Redding Rock bed. Otter trawl hauls at randomly selected points were the first-stage units and a random subsample of the catch from each haul constituted the second stage. Formulas are given for unbiased estimators of relative abundance and for associated variances. Several allocations of sampling effort are discussed and applied to data from the Fall, 1965 Survey. Proportional allocation at the first stage coupled with a constant sample size at the second stage are recommended for use because this combination is operationally the most feasible.

INTRODUCTION

Estimates of year-class relative abundance derived from statistically designed research vessel cruises possess certain advantages over similar determinations based on commercial fisheries data. Principal among the advantages are internally generated estimates of precision as well as unbiased estimates of the abundance parameters. These are not generally obtainable from commercial data, since the behavior of the fishing fleet cannot be controlled. Only precarious assumptions on the randomness of fishing or of the fished population allow one to claim these desirable properties for statistics derived from commercial fishing. A statistically designed survey also can eliminate problems associated with a lack of fishing in areal strata and with the use of biased ratio-type estimates. An extensive discussion of other problems and considerations which are involved in making relative abundance estimates from commercial fishing data is contained in the report of a symposium on the measurement of abundance of fish stocks (Gulland, 1964).

High cost is the main disadvantage of research vessel surveys. However, a high cost is certainly justified if the relative abundance estimates are to be incorporated into a mathematical population model for predicting yields and regulating a fishery. Without measures of statistical variability for the component parts, there can be no estimates of precision for the yield predicted by the whole model, and this may be of considerable economic importance.

This sampling plan was designed to estimate the relative abundance of ocean shrimp from trawl surveys in the Klamath River-Redding Rock bed off the northern California coast. The methods should be applicable to other types of aquatic populations as well. Relative abundance estimates will be used to compute mortality rates and also to evaluate the validity of similar determinations from commercial fishing data.

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We first give a narrative account of the sampling and estimating procedures, then results from a survey, derivations of the estimating formulas, and finally a discussion of sampling efficiency.

SAMPLING AND ESTIMATING PROCEDURES

A region which contains the population of interest must be delineated. Since estimated relative abundance is a function of the size of area sampled, this area will ordinarily remain constant from survey to survey. Otherwise, special weighting procedures are required. We assume that the sampled region will be divided into areal strata based on some prior knowledge of the population or for administrative convenience. However, simple random sampling over the entire region can be carried out if there is no basis for stratification. Stratum boundaries, unlike those of the region, can be changed from survey to survey without affecting the overall estimate of relative abundance.

The survey is accomplished by selecting random starting points for the constant-length hauls (first-stage sampling units) within each stratum. Haul directions are arbitrary. When a haul is completed, the catch is placed in containers divided into serially numbered compartments. This procedure is carried out so that consecutively numbered compartments (second-stage sampling units) are filled. A table of random numbers is then used to select the subsample for complete enumeration with respect to the characteristics of interest. In order to obtain an estimate of the standard error, at least two first-stage units must be selected from each stratum and one second-stage unit drawn from each first-stage unit. If separate estimates of the variance components from the first and second stages are desired, at least two second-stage units are required from each first-stage unit.

The estimated catch of a single haul is the product of the reciprocal of the second-stage sampling fraction and the sample mean per compartment. There may, of course, be more than one sample mean for each haul, depending upon the number of characteristics being estimated. Relative abundance estimates for each stratum are the means of the estimated haul catches; relative abundance estimates over the entire survey area are weighted means of the stratum estimates using stratum areas as the weights. Stratum and population variance estimates are obtained from standard formulas for unbiased estimates of the variance of a mean and the variance of a weighted mean. The sample of haul starting points is assumed to be from an infinite population. Explicit formulations for the mean and variance estimates are given later.

While this procedure is similar to two-stage sampling plans described in standard sampling texts such as Sukhatme's (1954), it differs in the treatment of the first stage since we assume an infinite population of sampling units.

RESULTS FROM THE FALL, 1965 SURVEY

The survey area of 269.9 square nautical miles was divided into 14 strata ranging in size from 11.2 to 32.4 square miles. Stratum boundaries were determined by examining commercial fishing logbooks and

research vessel survey data with respect to the homogeneity of catches in terms of pounds of shrimp per unit haul time. Four strata, constituting about 36% of the total area, are regions of historically small catches and it was arbitrarily decided to apportion only one-fourth of the hauls to them. These hauls were allocated among the four strata in proportion to their areas and the remaining three-fourths of the hauls were also proportionally allocated to the other strata.

Random haul starting points in units of seconds of latitude and longitude were independently selected for each stratum. Since the use of a random number table for the selection of points in the irregularly bounded strata would have been a very lengthy procedure, a computer program was written to produce the random haul coordinates. For each stratum, the program generates pairs of random numbers, checks them against the stratum boundaries, and prints a list containing the desired number of haul coordinates.

Hauls were one-half mile in length with a 41-ft. semiballoon otter trawl. The catches were placed in boxes divided into 80 compartments. Second-stage samples consisted of two compartments except that when only one compartment was filled it constituted the entire sample. Computer-prepared random number tables of various ranges were used so the subsample selections could be made rapidly.

One hundred and seventeen hauls were completed during the Fall, 1965 Survey. The proportional allocation described previously was not achieved completely, since vessel time was a limiting factor and some of the scheduled hauls were not made. Nevertheless, the unbiased property of the estimates is not dependent on any particular allocation.

Mean-per-haul estimates of the number in age groups I through III and of their combined numbers and weights were calculated, as were the area-weighted means or relative abundance estimates over the entire survey area (Table 1). The standard errors associated with the relative abundance estimates are larger than one would like, considering the number of hauls involved. However, an inherent high variability seems characteristic of marine populations and usually there is no remedy except larger samples. A discussion of the efficiencies which could have been obtained under various allocation schemes occurs later.

FORMULATION OF THE ESTIMATORS

The notations and definitions which follow are in terms of the number of shrimp of all ages. Since the same procedure is used for estimating any population characteristic of interest, the formulas apply as well to the estimation of numbers or weights in individual age groups or any combination of them. The object of our estimation, the relative number of shrimp contained in a prescribed area, is $\bar{Y} \dots = qY \dots$, where $Y \dots$ is the total number of shrimp in the area and q is a constant. If we let $q = \bar{a}\bar{p}/A$, with \bar{a} the mean area swept by the net during a standard haul, \bar{p} the mean proportion of shrimp caught from the water column over the swept area of a standard haul, and A the entire survey area, then $\bar{Y} \dots$ is the relative abundance pertinent to the survey procedure. It clearly must be assumed that \bar{a} , \bar{p} and A are constants in order for the relative abundance to be useful. We also

TABLE 1
Estimates of the Fall, 1965 Ocean Shrimp Mean Catch per Haul by Stratum and Relative Abundance Estimates for the Entire Survey Area

[illegible]

must adopt the premise that the quantities being estimated remain constant during the survey.

From the definitions,

A_h Area of stratum h ; $h = 1, 2, \dots, L$,

$Y_{h..}$ Total number of shrimp in stratum h ,

and

$$W_h = A_h/A,$$

$$\bar{Y}_{h..} = \bar{ap}Y_{h..}/A_h,$$

$$A = \sum_{h=1}^L A_h,$$

$$Y_{...} = \sum_{h=1}^L Y_{h..},$$

we obtain

$$\bar{Y}_{...} = \sum_{h=1}^L W_h \bar{Y}_{h..}. \quad (1)$$

It is further assumed that the catch of the i th haul in the h th stratum is an unbiased estimate of $\bar{Y}_{h..}$, or $E(M_{hi}\bar{Y}_{hi.}) = \bar{Y}_{h..}$,

where

M_{hi} Number of cells filled on the i th haul; $i = 1, 2, \dots, n_h$,

$\bar{Y}_{hi.}$ Mean number of shrimp per filled cell on the i th haul,

n_h Number of hauls in the h th stratum.

This assumption will be clearer if we consider $M_{hi}\bar{Y}_{hi.}$ as the product of three mutually independent random variables, Y'_{hi} , a , and p , with expectations $Y_{h..}/A_h$, \bar{a} , and \bar{p} . Then $E(M_{hi}\bar{Y}_{hi.}) = E(apY'_{hi}) = \bar{ap}Y_{h..}/A_h = \bar{Y}_{h..}$.

The following definitions referring to the h th stratum are also needed:

y_{hij} Number of shrimp in the j th cell from the i th haul,

m_{hi} Number of cells in the sample from the i th haul,

$$\bar{y}_{hi.} = \frac{1}{m_{hi}} \sum_{j=1}^{m_{hi}} y_{hij},$$

$$\bar{y}_{h..} = \frac{1}{n_h} \sum_{i=1}^{n_h} M_{hi} \bar{y}_{hi.},$$

as is the result, $E(\bar{y}_{hi.} | M_{hi}) = \bar{Y}_{hi.}$.

A logical choice for an estimator of $Y_{h..}$ is the mean of the estimated haul totals given by

$$\bar{y}'_h = \frac{1}{n_h} \sum_{i=1}^{n_h} M_{hi} \bar{y}_{hi} .$$

That \bar{y}'_h is unbiased can be seen with the use of standard theorems on conditional expectation (Parzen, 1962). Thus,

$$\begin{aligned} E(\bar{y}'_h) &= \frac{1}{n_h} \sum_{i=1}^{n_h} E(M_{hi} \bar{y}_{hi}) \\ &= \frac{1}{n_h} \sum_{i=1}^{n_h} E[M_{hi} E(\bar{y}_{hi} | M_{hi})] \\ &= \bar{Y}_{h..} . \end{aligned} \tag{2}$$

From (1) and (2) it follows that $\bar{y}'_h = \sum W_h \bar{y}'_h$ is an unbiased estimator of $Y_{h..}$.

The variance of the estimated relative abundance is given by

$$V(\bar{y}'_h) = \sum_{h=1}^L W_h^2 V(\bar{y}'_h) . \tag{3}$$

In developing the expression for $V(\bar{y}'_h)$ we assume that $V(y_{hij} | M_{hi}) = S_{hi}^2$ and $V(M_{hi} \bar{y}_{hi}) = S_{bh}^2$. That is to say, cell observations have a constant variance within each haul and haul totals have a constant variance within each stratum. The variance of the stratum estimate \bar{y}'_h is

$$V(\bar{y}'_h) = E(\bar{y}'_h - \bar{Y}_{h..})^2 ;$$

and this is separated into within- and between-haul components by subtracting and adding $\bar{y}_{h..}$ before squaring to obtain

$$\begin{aligned} V(\bar{y}'_h) &= E(\bar{y}'_h - \bar{y}_{h..})^2 + E(\bar{y}_{h..} - \bar{Y}_{h..})^2 \\ &\quad + 2E[(\bar{y}'_h - \bar{y}_{h..})(\bar{y}_{h..} - \bar{Y}_{h..})] . \end{aligned}$$

Using theorems on conditional expectation and conditional variance it can be shown that

$$\begin{aligned} E(\bar{y}'_h - \bar{y}_{h..})^2 &= \frac{1}{n_h} E \left[\frac{M_{hi}(M_{hi} - m_{hi})}{m_{hi}} S_{hi}^2 \right] , \\ E(\bar{y}_{h..} - \bar{Y}_{h..})^2 &= \frac{1}{n_h} S_{bh}^2 , \end{aligned}$$

and

$$E[(\bar{y}'_h - \bar{y}_{h..})(\bar{y}_{h..} - \bar{Y}_{h..})] = 0.$$

Then,

$$V(\bar{y}'_h) = \frac{1}{n_h} E\left[\frac{M_{hi}(M_{hi} - m_{hi})}{m_{hi}} S_{1hi}^2\right] + \frac{1}{n_h} S_{bh}^2, \quad (4)$$

where the within- and between-hauls components are the first and second terms on the right-hand side respectively.

To estimate $V(\bar{y}'_h)$ we use

$$s_{th}^2 = \sum_{i=1}^{n_h} \frac{(M_{hi}\bar{y}_{hi.} - \bar{y}'_h)^2}{n_h - 1}.$$

The unbiasedness of s_{th}^2 can be seen by expanding and taking the expectation of its numerator to obtain,

$$\begin{aligned} E[(n_h - 1)s_{th}^2] &= \sum_{i=1}^{n_h} E[M_{hi}^2 E(\bar{y}_{hi.}^2 | M_{hi})] - n_h E(\bar{y}'_h{}^2) \\ &= n_h E\left[\frac{M_{hi}(M_{hi} - m_{hi})}{m_{hi}} S_{1hi}^2 + (M_{hi}\bar{Y}_{hi.})^2\right] \\ &= n_h [V(\bar{y}'_h) + \bar{Y}_{h..}^2]. \end{aligned}$$

Substituting from (4) and simplifying gives the desired result,

$$E\left(\frac{s_{th}^2}{n_h}\right) = V(\bar{y}'_h).$$

It follows that an unbiased estimator for $V(\bar{y}')_h$ is

$$\hat{V}(\bar{y}')_h = \sum_{h=1}^L \frac{W_h^2 s_{th}^2}{n_h}. \quad (5)$$

An unbiased estimator for the within-hauls component of $V(\bar{y}'_h)$ is

$$\frac{s_{wh}^2}{n_h} = \frac{1}{n_h^2} \sum_{i=1}^{n_h} \frac{M_{hi}(M_{hi} - m_{hi})}{m_{hi}} s_{1hi}^2,$$

where

$$s_{1hi}^2 = \frac{\sum_{j=1}^{m_{hi}} (\bar{y}_{hij} - \bar{y}_{hi.})^2}{m_{hi} - 1}.$$

The unbiased character of s_{wh}^2 can be verified by applying the previously mentioned theorems on conditional expectation, and an unbiased estimator for the between-hauls component is clearly

$$\frac{s_{bh}^2}{n_h} = \frac{s_{th}^2}{n_h} - \frac{s_{wh}^2}{n_h}.$$

ALLOCATION OF THE SAMPLE

The initial surveys were carried out with modified proportional allocation at the first stage and a constant sample size of two at the second stage, as mentioned previously, since no prior information on first- and second-stage variance components was available.

Here we will examine several methods of allocating sampling between strata and between the two stages: proportional sampling at both stages, proportional sampling at the first stage with a constant sample size at the second stage, and unrestricted first-stage sampling with a constant within-stratum sample size at the second stage.

For any given type of allocation it is necessary to determine the distribution of sampling effort between the stages so that the variance will be a minimum for a fixed cost, or so that the cost will be minimized for a fixed variance. Once these determinations are made, the efficiencies of the allocations may be compared.

A simple linear cost function suitable for the trawl surveys is

$$C = c_1 \sum_{h=1}^L n_h + c_2 \sum_{h=1}^L n_h (\bar{m}_h - 1), \quad (6)$$

where

C	total cost of the survey,
c_1	cost of sampling one first-stage unit (haul),
c_2	cost of sampling one second-stage unit (cell),
\bar{m}_h	mean second-stage sample size in stratum h .

The second term on the right contains $(\bar{m}_h - 1)$ rather than \bar{m}_h , because one second-stage unit can be processed at virtually no additional cost while the next haul is in progress. It also should be noted that C does not include costs involved in vessel travel to and from the survey area nor costs incurred when the vessel cannot operate due to rough weather; such fixed costs have no effect on the allocations between stages.

Because in this case it is much easier to calculate costs for a fixed variance than the converse, we have set up the following function from (3), (4), and (6) with a constraint on the variance. Sample sizes are obtained by minimizing

$$F = \sum_{h=1}^L [n_h(c_1 - c_2) + n_h \bar{m}_h c_2] \quad (7)$$

$$+ \lambda \left[\sum_{h=1}^L W_h^2 \left\{ \frac{1}{n_h} E \left[\frac{M_{hi}(M_{hi} - m_{hi})}{m_{hi}} S_{1hi}^2 \right] \right. \right. \\ \left. \left. + \frac{1}{n_h} S_{bh}^2 \right\} - V \right]$$

where λ is a Lagrange multiplier and V is the fixed variance.

To determine the allocation with the first-stage sample proportional to the stratum size and with the second-stage sample size a constant, we let $k_1 = n_h/W_h$ and $k_2 = m_{hi}$ in (7). Then solve $\partial F/\partial k_1 = 0$, $\partial F/\partial k_2 = 0$, (3), and (4) for k_1 and k_2 . This procedure yields

$$k_2 = \sqrt{\frac{(c_1 - c_2) \sum_{h=1}^L W_h E(M_{hi}^2 S_{1hi}^2)}{c_2 \sum_{h=1}^L W_h [S_{bh}^2 - E(M_{hi} S_{1hi}^2)]}}, \quad (8)$$

and

$$k_1 = \frac{1}{V} \left\{ \sum_{h=1}^L W_h [S_{bh}^2 - E(M_{hi} S_{1hi}^2) + E(M_{hi}^2 S_{1hi}^2)/k_2] \right\}. \quad (9)$$

The allocation with proportional sampling at both stages is found by letting $k_1 = n_h/W_h$ and $k_2 = m_{hi}/M_{hi}$ in (7) and (4). Solving $\partial F/\partial k_1 = 0$, $\partial F/\partial k_2 = 0$, and (3) gives

$$k_2 = \sqrt{\frac{(c_1 - c_2) \sum_{h=1}^L W_h E(M_{hi} S_{1hi}^2)}{c_2 \sum_{h=1}^L W_h \bar{M}_h \sum_{h=1}^L W_h [S_{bh}^2 - E(M_{hi} S_{1hi}^2)]}}, \quad (10)$$

and

$$k_1 = \frac{1}{V} \left[\frac{1 - k_2}{k_2} \sum_{h=1}^L W_h E(M_{hi} S_{1hi}^2) + \sum_{h=1}^L W_h S_{bh}^2 \right]. \quad (11)$$

When no restrictions are placed on first-stage sampling and the second-stage sample size is constant within strata, let $k_{2g} = m_{gi}$ in (7) and solve $\partial F/\partial n_g = 0$, $\partial F/\partial k_{2g} = 0$, and (3) to obtain sample sizes for the g th stratum. The solutions are

$$k_{2g} = \sqrt{\frac{(c_1 - c_2) E(M_{gi}^2 S_{1gi}^2)}{c_2 [S_{bg}^2 - E(M_{gi}^2 S_{1gi}^2)]}} \quad (12)$$

and

$$n_g = \frac{W_g}{W} \sqrt{\frac{c_2 H_g}{c_1 - c_2 + c_2 k_{2g}}} \sum_{h=1}^L \frac{k_{2h} W_h H_h}{\sqrt{E(M_{hi}^2 S_{1hi}^2)}} \quad (13)$$

where

$$H_h = S_{bh}^2 + \frac{E(M_{hi}^2 S_{1hi}^2)}{k_{2h}} = E(M_{hi}^2 S_{1hi}^2) \quad .$$

By calculating what the Fall, 1965 Survey would have cost under each of these three types of allocation for the precision actually obtained, we may compare the relative efficiencies of the sampling schemes. Although five quantities were estimated from the survey and each may be associated with a different total cost for the attained precision, a cost calculation for the number estimates in age groups I and II should suffice for comparative purposes. Of course, in actual practice one would try to provide sufficient sampling funds so that the standard error of the estimate with the lowest precision was less than a predetermined maximum.

The cost formula was evaluated with $c_1 = \$125.00$ and $c_2 = \$0.58$. Vessel operation costs and the wages of scientific personnel on board the ship are included in c_1 , while c_2 is the cost of processing one second-stage sample ashore. Applying formulas (6) through (13) to data from the Fall, 1965 Survey gave total costs and values yielded by k_1 and k_2 (Table 2) and by n_g and k_{2g} (Table 3). In the cost calculations, the actual estimates of k_1 and k_2 were used for the allocations which employ proportional sampling at the first stage. Costs of the allocations with unrestricted first-stage sampling were computed with n_g and k_{2g} rounded upward to integers.

TABLE 2

Values of k_1 , k_2 and C From the Fall, 1965 Survey for the Two Plans With Proportional First-stage Sampling to Yield the Precision Actually Attained

	Proportional second stage		Constant second stage	
Age group -----	I	II	I	II
k_1 -----	132.0	105.2	132.7	107.5
k_2 -----	0.018	0.053	2.3	8.6
C -----	\$16,530	\$13,338	\$16,689	\$13,913

For the Fall, 1965 Survey, C was \$14,683. With proportional allocation at both stages, the total cost would have been \$16,530 or \$13,338 in order to estimate the relative numbers in age groups I or II, respectively, at the same levels of precision actually obtained. Also, for the same precision, the allocation with proportional sampling at the first stage and a constant second-stage sample size yielded C's of \$16,689 and \$13,913, while the plan using unrestricted first-stage sam-

TABLE 3

Values of n_g , k_{2g} and C From the Fall, 1965 Survey for the Plan With Unrestricted First-stage Sampling and a Constant Second-stage Sample Size to Yield the Precision Actually Attained

Stratum	Age Group I		Age Group II	
	n_g	k_{2g}	n_g	k_{2g}
1.....	2	9	3	7
2.....	3	4	2	12
3.....	11	1	5	3
4.....	15	3	7	8
5.....	5	2	3	10
6.....	10	1	13	10
7.....	4	4	2	12
8.....	1	4	1	8
9.....	7	3	4	7
10.....	2	3	1	13
11.....	2	4	2	5
12.....	2	4	2	12
13.....	6	6	4	6
14.....	2	1	3	12
Totals.....	72		52	
C	\$9,078		\$6,727	

pling and constant second-stage sampling within strata could have been carried out for the relatively low costs of \$9,078 and \$6,727.

It is notable that the cost formula, when applied to plans which use proportional allocation at the first stage, gives costs somewhat higher than the actual expense of the Fall, 1965 Survey for age group I and costs lower than those of the survey for age group II. However, because the sample sizes involved in estimating both the first- and second-stage variance components were rather small, the differences between the cost of the actual survey and the calculated costs of the two plans using first-stage proportional sampling probably are not significant. The plan with unrestricted first-stage sampling is clearly more efficient than either of the proportional allocation schemes, as evidenced by its substantially lower cost figures.

Examination of equations (8) through (13) reveals that all of these allocation schemes require an advance knowledge of the first- and second-stage variance components. The sample sizes of the plans that allocate proportionally at the first stage depend mainly on relative magnitudes of the first- and second-stage variance components averaged over the strata. The more efficient plan with unrestricted first-stage allocations, however, requires for each stratum a knowledge of the first-stage variance components, as well as of the mean of the second-stage components. The practicality of the unrestricted or optimum allocation then depends on the ability to predict these within-stratum variance components.

Unfortunately, prediction of the variance components needed for optimum allocation seems virtually impossible in the case of the ocean shrimp surveys. If we let f_{1hi} denote the fraction of C which would have been expended on the i th stage of the h th stratum during the Fall,

1965 Survey and let f_{2hi} represent the corresponding quantity from the Spring, 1966 Survey, then $(f_{2hi} - f_{1hi})/f_{1hi}$ estimates the relative change in sampling costs between the two surveys for stage i of stratum h in the plan with first-stage optimum allocation. A perfect prediction would yield a value of zero for the relative change. Relative changes in sampling costs for age group I between the Fall, 1965 Survey and the Spring, 1966 Survey range from -10.675 to 0.863 (Table 4). The means of the absolute values of the relative changes are 1.65 and 2.14 for the first and second stages, respectively; the change in the first-stage allocation is, of course, the more serious in terms of cost and precision. An examination of data from the surveys indicated that the variance components from individual strata continued to be quite variable and not useful for predicting optimum sampling allocations.

TABLE 4
Relative Changes in Sampling Costs Between the Fall, 1965 and the Spring, 1966 Surveys for the Plan With Unrestricted First-stage Allocation

Stratum.....	1	2	3	4	5	6	7
First stage.....	+0.314	-3.579	+0.751	+0.725	-1.199	+0.863	+0.657
Second stage.....	-0.447	-3.579	+0.257	+0.451	-5.531	+0.594	+0.833
Stratum.....	8	9	10	11	12	13	14
First stage.....	-0.372	+0.804	+0.314	-1.748	-10.675	+0.771	+0.314
Second stage.....	-0.040	+0.612	+0.553	-6.510	-4.804	+0.694	-5.000

For the plan which uses proportional sampling at both stages, the relative change figure for the first stage was -0.003 and the figure for the second stage was 0.636 ; for the plan with a constant second-stage sample size, the figures were -0.007 and 0.593 .

The choice of a useful allocation scheme for the shrimp surveys is clearly limited to the two plans with proportional allocation at the first stage since the unrestricted allocation, although the most efficient, is apparently unobtainable. Of these two, the plan with a constant second-stage sample size is recommended because its operational simplicity more than compensates for its slight deficiencies in precision and stability of allocation.

ACKNOWLEDGMENTS

I wish to thank Daniel W. Gotshall and Walter A. Dahlstrom of the California Department of Fish and Game for supplying data on the historical distribution of shrimp in the survey area and for advice on the operational feasibility of the sampling procedures. I am also indebted to Jo Ann Spaulding, now with the California Department of General Services, for stratifying the survey area and for writing the computer programs which generated random haul coordinates and random subsampling numbers.

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FIRST REPORT OF THE CRAB FAMILY CHIROSTYLIDAE OFF CALIFORNIA, AND DESCRIPTION OF A NEW SPECIES OF *CHIROSTYLUS*¹

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**A new crab, *Chirostylus perarmatus* (Decapoda, Anomura, Chirostyli-
dae), is described from deep water off southern California, and its re-
lationship to other eastern Pacific *Chirostylus* is discussed. Both the
genus and the family are new to Californian waters.**

INTRODUCTION

In the course of fishery investigations, California Department of Fish and Game vessels frequently capture rare and unusual organisms. In early 1961 several crabs collected during one of these investigations were brought to the Allan Hancock Foundation for identification. They were immediately recognized as *Chirostylus* (family Chirostylidae), a genus and family unreported from Californian waters. Subsequent study indicated that they could not be placed in any described species.

The specimens were collected by the California Department of Fish and Game vessel *Alaska* in deep water at Station 16 (61A1-16). They were taken in a beam trawl along with 14 species of fishes, a spiny sea urchin (probably *Allocentrotus*), two species of sea pen, a squid (*Rossia pacifica*), jellyfish, and several species of crustaceans.

The Chirostylidae are related to the Galatheidae, a family represented in Californian waters by at least eight species. The best known of these is the pelagic red crab, *Pleuroncodes planipes* Stimpson, which is normally confined to Mexican waters, but attracts a good deal of attention in California when it comes northward during years of warm ocean temperatures (Glynn, 1961; Radovich, 1961). The rest of the Californian galatheids live in deep water and are seldom seen by the casual observer, but they are frequently caught by fisheries and research vessels. *Chirostylus* bears a superficial resemblance to some of these, particularly *Munida*.

SYSTEMATIC ACCOUNT

The Chirostylidae belong to section (formerly tribe) Anomura and superfamily Galatheidea, which also includes the marine families Porcellanidae (porcelain crabs or rocksliders) and Galatheidae, as well as the South American freshwater family Aeglididae. Schmitt (1921) presents a key to the anomuran families known from California; the portion of this key dealing with the Galatheidea may be modified as follows to include the Chirostylidae:

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Body depressed, abdomen bent under, folded upon itself or against thorax, often with a transverse suture on telson (superfamily *Galatheidca*).

1. Abdomen bent upon itself, but not folded against thorax; body shrimp-like; first legs greatly elongated, slender.

- a. Telson with a transverse fissure and folded beneath the preceding abdominal somites along with the tail-fan.

Chirostylidae

- b. Telson without a transverse fissure and not folded beneath the preceding abdominal somites.

Galatheidae

2. Abdomen folded against thorax; body crab-like; first legs only moderately elongate, stout.

Porellanidae

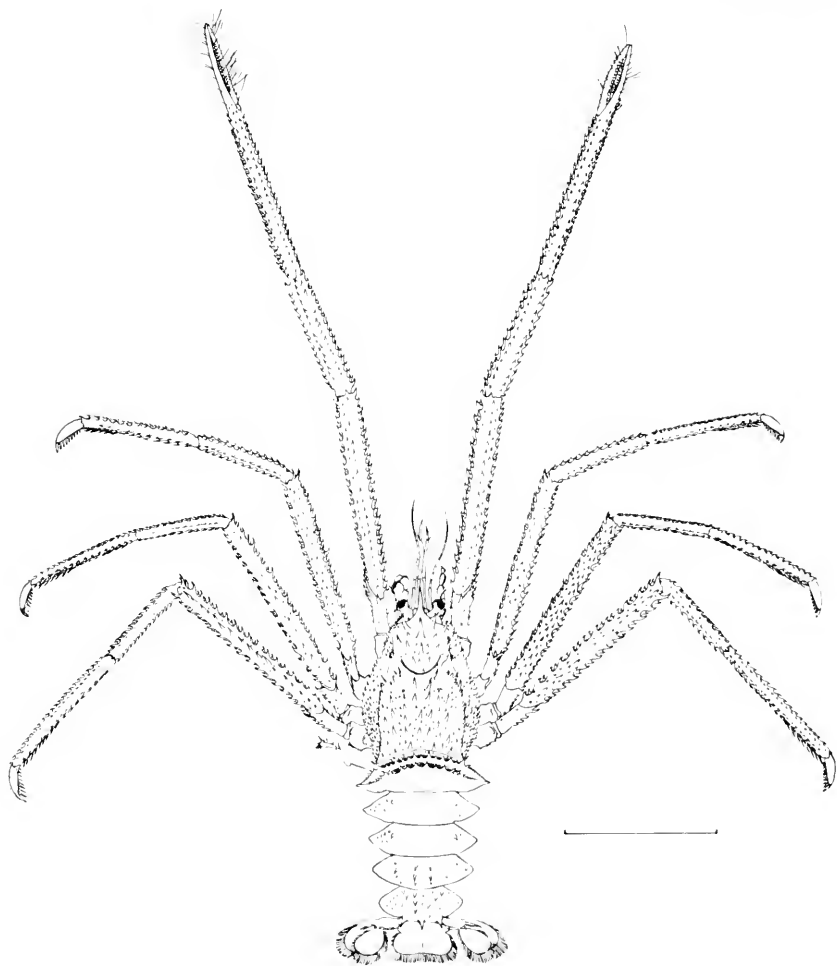


FIGURE 1—Holotype of *Chirostylus perarmatus*. (Scale represents 20 mm.)

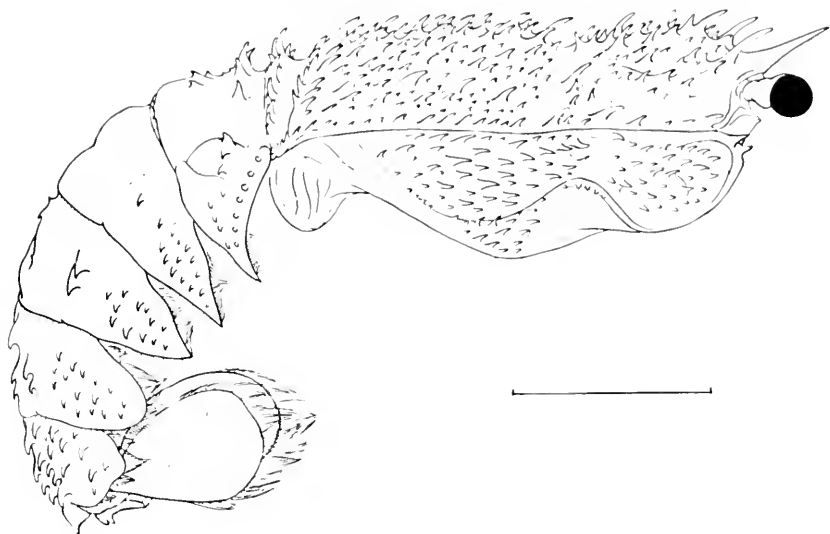


FIGURE 2—Holotype of *Chirostylus perarmatus*; carapace and abdomen in lateral view. (Scale represents 10 mm.)

Family Chirostylidae

Body shrimp-like. Abdomen bent upon itself but not folded up against the thorax; telson with a transverse fissure and folded beneath the preceding abdominal somites along with the tail-fan. First legs chelate, greatly elongated, slender. Antennal peduncle five-segmented, the second and third article being distinctly separated; flagellum of moderate length.

Genus *Chirostylus* Ortmann

Carapace convex, the lateral borders inflated and not sharply defined; rostrum spiniform; antennal acicle wanting; chelipeds and first three pairs of walking legs slender and of enormous length.

Chirostylus perarmatus sp. n.

Holotype

Male, AHF 6138; deposited in the Allan Hancock Foundation. Collected January 20, 1961, by California Department of Fish and Game vessel *Alaska* at Station 16 (61A1-16), north of Anacapa Island, California, $34^{\circ} 05.8' N$, $119^{\circ} 23.3' W$ to $34^{\circ} 06.0' N$, $119^{\circ} 24.3' W$; 125 fathoms, green mud bottom.

Paratypes

Four males and five females, all collected with the holotype. At present these specimens are in the Allan Hancock Foundation, but part of the material is to be distributed elsewhere.

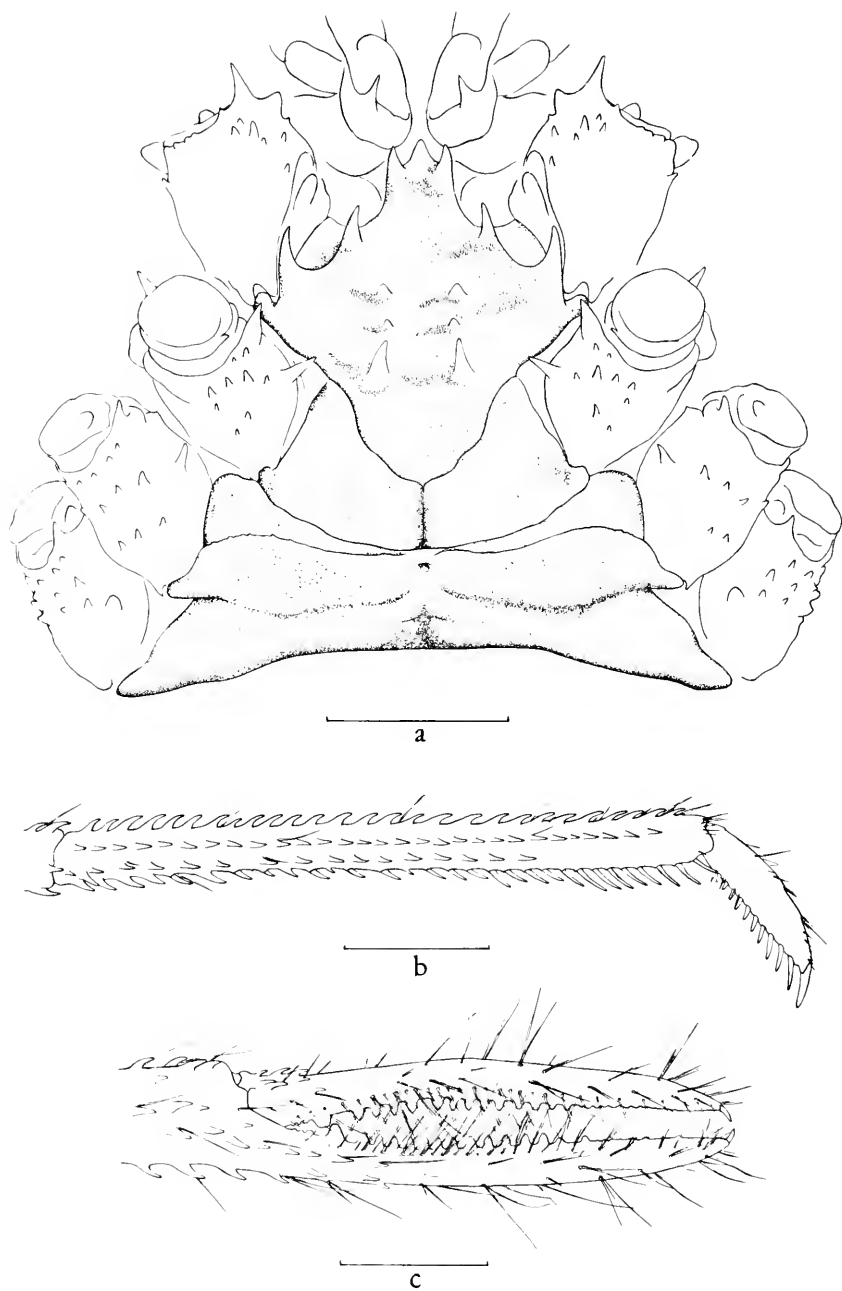


FIGURE 3—Holotype of *Chirostylus perarmatus*. A, sternal plastron; B, right walking leg; C, fingers of right chela. (Scales represent 5 mm.)

Description

The carapace, including the rostrum, is about twice as long as its greatest width and as long as the first six segments of the abdomen; it is narrowest anterior to the cervical groove. The lateral margins are subparallel and slightly convex behind the cervical groove, which forms a deep, transverse depression separating the gastric and cardiac regions and extends obliquely forward on either side to separate the gastric region from the hepatic regions. The gastric region is swollen and well defined; the cardiac region is poorly defined laterally and posteriorly. The posterior branchial regions meet in the midline. The carapace is thin and semitransparent; except for the rostrum and the area near the cervical groove it is densely covered with thorn-shaped, forward-pointing spines. There are seven particularly prominent spines in the gastric region, one in each hepatic region, and one in the anterior branchial region at either side of the transverse portion of the cervical groove. On the posterior branchial regions the large spines tend to be arranged in uneven longitudinal rows, with the largest ones near the midline. Many spinules are interspersed with the large spines, especially on the posterior branchial regions. In the smaller specimens, fewer of these spinules are developed and they may nearly be absent on the gastric region.

The sides of the carapace are swollen laterally and visible in dorsal view; they are evenly and densely covered with small spines.

The rostrum is a slender, straight spine, broadened at its base; it is unarmed and sharply upturned.

The eyes are short, not reaching the tip of the rostrum.

The stylocerite of the antennules is a short, rounded, unarmed lobe.

The antennae are slender and nearly as long as the carapace. Their flagella extend beyond the flagella of the antennules.

The outer maxillipeds have a well-developed coxal spine; there is a small spine at the outer distal margin of the merus, and a subproximal and a distal spine on the outer margin of the carpus; the propodus is unarmed.

The sternite of the outer maxillipeds is very narrow and pointed anteriorly; on either side of it is a large, stout spine, placed just behind the margin at the base of the maxillipeds. The sternite of the chelipeds has four large spines, two on either side, along its anterior border; on the posterior portion of this sternite is a pair of large spines, one on either side of the midline; anterior to these spines and roughly in line with them are one or two pairs of well-developed tubercles or spinules. Two more pairs of barely perceptible tubercles are sometimes developed anterior to these, the most anterior pair being located on a line with the inner pair of large spines. The sternites of the walking legs are unarmed.

The chelipeds are very long and slender, approximately four to five times the length of the carapace; they tend to be proportionately longer in smaller individuals. The lower surface of the coxa is armed with a large inner distal spine and covered with a number of spinules. The basi-ischium has a spine at its upper distal margin and numerous spines, arranged in four irregular rows, on its outer and lower surfaces. The merus, carpus, and palm are armed on all sides with even, longi-

tudinal rows of close-set spines; between these rows the surface is flattened rather than convex. Interspersed with the rows of spines are long, scattered hairs. The palm is about one and a half to two times as long as the fingers, which are slightly curved and gaping, their inner edges with a row of blunt teeth and with many hairs; they are otherwise smooth except for a few minute spinules on their lateral and dorsal surfaces near the proximal end.

The walking legs are very long, reaching or surpassing the distal end of the carpus of the cheliped. The lower surface of the coxa has a large inner distal and inner subdistal spine; these spines are especially prominent on the first two pairs of walking legs. The basischium, merus, and carpus are armed much like the corresponding articles of the chelipeds. The distal third of the propodus is compressed and slightly broadened, and the lower margin of the segment is armed with a row of slender, movable spines; the spines near the distal end are elongate. The dactyl is short, unarmed on its dorsal and lateral surfaces, and provided with a strong, slender terminal claw; its lower margin has a series of slender, movable spinules which increase in size distally.

The first abdominal segment has a transverse row of about 12 to 18 spines; it has no pleura but their position is marked by a stout, pointed tubercle on either side. The second segment has a transverse row of five to eight spines on its proximal margin; in larger individuals there is a transverse row of two to four small conical tubercles near the midline of the somite and about halfway between its proximal and distal margins. Segment 2 also has a small group of large, pointed conical tubercles (usually three to five in mature specimens) on either side at the junction with the pleura, and the latter have a row of small conical spines or teeth along their proximal margin and sometimes several more spines on the pleural surface. The third abdominal segment is unarmed except for one or two spines on either side at the junction with the pleura; in some small individuals these spines are wanting. The fourth segment is unarmed except for one to three spines on either side at the junction with the pleura. The fifth segment has a double longitudinal row of three or four spines on its surface, and a longitudinal row of two to four spines on either side at the junction with the pleura. The sixth segment has many strong spines over the entire surface, tending to form longitudinal rows; the distal margin has three spines which overhang the telson. The pleura of segments 3 through 6 have their surfaces armed with numerous spinules except in very small individuals (the pleura of segment 3 especially tend to lack or have a reduced number of these spinules). The portion of the telson proximal to the transverse fissure is covered with fine spinules; the distal portion is unarmed but covered with very fine, short setules.

Males have paired gonopods on abdominal segments 1 and 2, and rudimentary pleopods on segments 3 through 5. Females have paired pleopods on segments 2 through 5.

Measurements

The paratypes vary in size from 14.5 mm to 22.5 mm for males and 12.3 mm to 21.2 mm for females (length of the carapace including the

rostrum). Following are measurements of the holotype, expressed in millimeters.

Length of body when fully extended:	61.0		
Length of carapace, including rostrum:	26.0		
Greatest carapace width:	14.0		
Right cheliped:			
Coxa and basi-ischium:	7.0		
Merus:	41.0		
Carpus:	24.8		
Propodus:	24.8		
Propodus and pollex:	41.8		
Dactyl:	16.8		
Right walking legs:			
Coxa and basi-ischium:	7.0	7.0	7.0
Merus:	35.8	37.0	38.1
Carpus:	18.4	20.2	19.0
Propodus:	23.3	23.0	26.0
Dactyl:	6.3	5.9	5.5

Color

The specimens were bright pink after a few weeks of preservation in alcohol, but soon faded to white.

Derivation of name

Latin *per*—well, very much, and *armatus*—armed; in reference to the numerous spines on the carapace, legs, and abdomen.

RELATIONSHIPS

Only two species of *Chirostylus* were previously reported from the eastern Pacific: *C. milneedwardsi* (Henderson) was collected in southern Chile by the *Challenger* Expedition, and *C. defensus* (Benedict) off the Galapagos Islands by the *Albatross*. *C. milneedwardsi* differs from *C. perarmatus* in having the propodus of the outer maxillipeds armed, and abdominal segments 2 through 6 completely covered with transverse rows of spines. *C. defensus* is more closely allied to the new species. It resembles *C. perarmatus* in the shape and proportions of the carapace, in the armature of the abdomen, and in the lack of armature on the propodus of the outer maxillipeds.

At my request Fenner A. Chace, Jr., U. S. National Museum, compared drawings of the new species against the two syntypes of *Ptychogaster defenza* Benedict in that institution. He concluded (pers. comm.), "Comparison of your figures with the syntypes of *Ptychogaster defenza* leaves me without doubt that your *Chirostylus* is distinct. In *C. defensus* all of the major spines on the carapace and legs are longer and less numerous, and there are fewer small spines interspersed among the larger ones. This is especially true of the chelipeds, which have the spination much more widely spaced and irregular than in your specimen. The pair of spines at the anterior end of the sternum in *C. defensus* are no more than sharp tubercles, and they are set well back from the margin at the bases of the maxillipeds. The two pairs of prominent tubercles that are lined up with the posterior pair of sternal spines in the California specimen are entirely lacking in *C. defensus*. The fingers of the chelae in the Galapagos species have a wider gap and a more prominent tooth near the base of each finger, but

the succeeding teeth (in the gape) are smaller and less numerous (more widely spaced).''

C. pcrarmatus appears to be most closely related to an Indian Ocean species, *C. investigatoris* (Alcock and Anderson). From the published illustrations and descriptive material, *C. investigatoris* appears to differ in details of the abdominal armature. In this species, the fifth segment is unarmed except laterally at the junction with the pleura, while *C. pcrarmatus* has a double row of spines on the fifth segment. Direct comparison of the two species might reveal other distinguishing characters.

ACKNOWLEDGMENTS

I am grateful to John E. Fitch, California Department of Fish and Game, for providing the specimens on which the description of *Chirostylus pcrarmatus* is based, and for the information relating to their capture. I am also indebted to Fenner A. Chace, Jr., U. S. National Museum, for clarifying the distinctions between the new species and *C. defensus*. The illustrations were prepared by Timothy Wyatt.

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PRIONOTUS XENISMA JORDAN AND BOLLMAN, A SEAROBIN NEW TO CALIFORNIA¹

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A triglid fish, *Prionotus xenisma* Jordan and Bollman, was found in the collections of the Museum of Natural History in Santa Barbara, California. The specimen was taken in a trawl net by a commercial fisherman in August 1958 in the vicinity of the Santa Barbara Channel Islands. This is the first positive record of this species from California.

While reorganizing the fish collection at the Santa Barbara Museum of Natural History in July 1966, I found an unidentified gurnard. The accompanying data stated that it had been taken by a commercial fisherman, H. Durrah of Santa Barbara, in August 1958 with a trawl net in the vicinity of the Santa Barbara Channel Islands.

The specimen did not match the description of *Prionotus stephanophrys*, the only gurnard listed for California waters (Hubbs, 1945), so I took it to John E. Fitch, California Department of Fish and Game, for identification. He recognized the fish as *Prionotus xenisma* Jordan and Bollman, which normally is taken from waters off the coast of Panama north to the southern part of the Gulf of California. This is the first positive record from California.

This species may be recognized by the deep rostral notch, the short pectoral fins, the presence of three free spines in the latter part of the first dorsal fin, and strong nasal spines. Since this specimen represents quite a northern range extension, I include a short description and also morphometric measurements (Table 1).

Dorsal fin, VII + III-10, deeply incised; anal fin, 9 (mutilated); pectoral, 8 + 3; pelvic, I, 5; caudal, 9; gill rakers in the 1st arch, 7; scales in lateral line, 42 (ca.); scales between lateral line and dorsal base, 7. Spines on the right side of the head: prerostral, 4 major and 3 minor to the inside; humeral, long and sharp, lying close to the body; preopercular, short and heavy, pointing outwards; postocular, small and blunt; opercular, long and pointing back; parital, short and blunt; nuchal, long and flat; preocular, pterotic, and sphenotic, all short and blunt.

Preserved in Baker's solution, the color is light brown, mottled with darker brown and black, with black on the pectorals, and a black spot on the margin of the first dorsal between the fourth and fifth spines.

ACKNOWLEDGMENTS

I wish to thank the following persons: Nelson Baker, Santa Barbara Museum of Natural History, for making the specimen available to me; John E. Fitch, California Department of Fish and Game, for identify-

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TABLE 1

Morphometric Measurements of the Santa Barbara Specimen of *Prionotus xenisma*

Measurements	Millimeters	Thousandths of standard length
Total length.....	71	--
Standard length....	59	--
Body depth.....	18	305
Depth of caudal peduncle.....	5	85
Length of caudal peduncle.....	4	68
Head length.....	27	457
Snout length.....	10	169
Orbit.....	6	107
Interorbital width.....	4	68
Length of maxillary.....	8	136
Snout to dorsal insertion.....	25	425
Snout to ventral insertion.....	40	678
Longest dorsal spine (1st).....	12	203
Base of the 1st dorsal.....	10	169
Longest dorsal ray (1st).....	8	136
Base of anal.....	14	238
Length of pectoral.....	18	305
Length of pelvic.....	18	305
Prerostreal spine length.....	2	63
Longest preopercular spine.....	5	85
Longest opercular spine.....	2	63

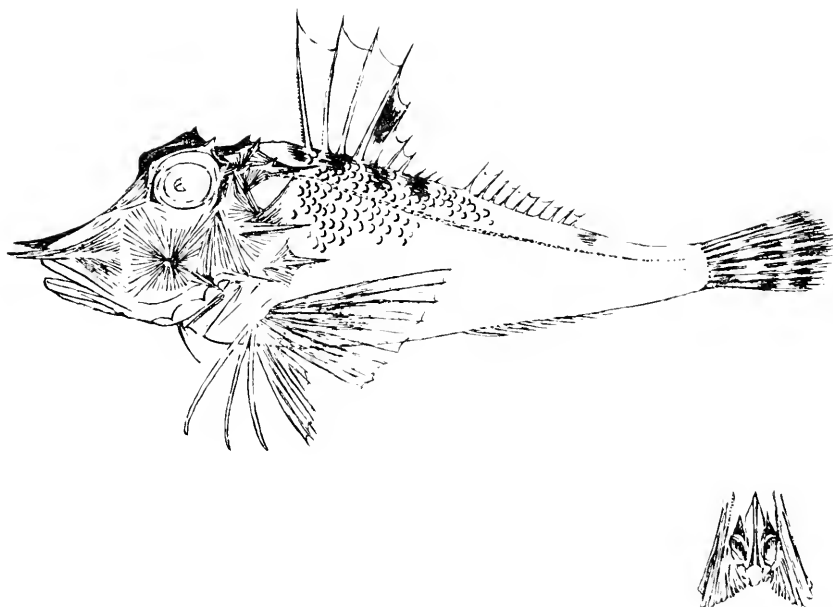


FIGURE 1—*Prionotus xenisma*, 74 mm TL, taken in the vicinity of the Santa Barbara Channel Islands, August 1958. This species is recognized by the deep rostral notch (see inset).

ing the specimen; Mrs. Thomas Rogers for her excellent drawing; and Herbert W. Frey, California Department of Fish and Game, for his helpful advice.

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FECUNDITY OF THE NORTHERN ANCHOVY, *ENGRAULIS MORDAX* GIRARD¹

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The ovaries and ovarian eggs of the northern anchovy are described briefly and compared with those of two other engraulids, *Cefengraulis mysticetus* and *Anchoa naso*. The number of eggs spawned in one batch by *E. mordax* was estimated to be 574 per g of total weight of the female compared with 836 for *C. mysticetus* and 326 for *A. naso*. Other factors used to determine biomass of adult anchovies from planktonic egg census data are discussed. The biomass of adult male anchovies in the commercial catch was about 75% of that of adult females. Therefore, for one spawning, 5.2×10^8 eggs would be produced per short ton of female anchovy or 3.0×10^8 eggs per short ton of adult biomass. The average number of times each female anchovy spawns in a year is not known and may vary from year to year.

INTRODUCTION

One of the objectives of the California Cooperative Oceanic Fisheries Investigations (CalCOFI) is to obtain censuses of the pelagic eggs and larvae of important fish species in the CalCOFI survey area. These data have been used directly as indices of relative sizes of the adult populations that produced them. Additional information, such as may be derived from fecundity studies, helps to refine these estimates of adult population size.

Northern anchovy larvae are the most abundant of any species taken in the survey area. More than a third of all larvae taken over the past 15 years have been anchovies, and they have increased in recent years both in total numbers and in percentage of all larvae taken. Plankton nets used in the CalCOFI surveys, which were designed to retain the larger, spherical planktonic fish eggs, do not retain all of the smaller, oblong anchovy eggs. Although supplementary hauls with finer mesh nets that retain all anchovy eggs have been used in recent years, presently available data on comparative abundance of the various fish species are based on larval abundance.

Although the literature contains considerable information on the northern anchovy, nothing has been published on its fecundity. The purpose of this paper is to present the fecundity data now available, and to discuss their application to the problems of estimating adult populations.

MATERIALS AND METHODS

The data on anchovy fecundity were obtained from 19 females collected off California or Baja California. Two were taken near the entrance to San Diego Bay, March 29, 1951; 11 were from bait samples

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collected near San Diego, March 29, 1960; 3 were collected at CalCOFI station 90.30, in the southern Santa Catalina Channel, July 20, 1953; and 3 at station 113.35, 55 nautical miles due north of San Benitos Islands, Baja California, September 21, 1952. The fish were preserved in formalin at the time of collection. The data, recorded after preservation, include standard length, weight, ovary weight, and number and size of eggs (Table 1). The methods used were similar to those of MacGregor (1957). Comparative data for the anchoveta, *Engraulis mysticetus*, are from Peterson (1961) and for *Anchoa naso* from seven females collected off Baja California.

TABLE 1
Measurements and Counts Related to Fecundity of *Engraulis mordax*
and *Anchoa naso*.

Standard length (mm)	Weight (g)	Gonad weight (g)	Advanced eggs		
			Number		Size range (mm)
			Total	Per g of fish	
<i>Engraulis mordax</i>					
97 -----	9.6	0.322	4,025	419	0.62-.78
102 -----	10.7	.766	8,617	808	.66-.84
106 -----	12.3	.389	6,956	566	.52-.66
108 -----	11.8	.501	5,487	465	.66-.76
108 -----	13.9	.859	10,160	731	.68-.80
109 -----	13.9	.602	7,150	514	.58-.70
109 -----	12.7	.730	8,516	673	.68-.86
111 -----	14.4	.536	8,049	559	.54-.62
111 -----	15.0	1.136	11,061	737	.68-.82
113 -----	15.1	.951	8,316	553	.68-.80
114 -----	14.4	.862	6,619	460	.61-.78
120 -----	21.5	.692	7,895	367	.56-.78
121 -----	18.6	.654	10,700	575	.52-.66
124 -----	21.0	1.288	15,519	739	.61-.82
128 -----	26.5	1.288	12,836	481	.70-.80
130 -----	24.5	1.812	18,579	758	.72-.86
130 -----	27.5	.832	12,962	471	.50-.66
131 -----	26.0	.642	10,289	396	.50-.58
138 -----	33.9	1.763	21,297	628	.62-.78
<i>Anchoa naso</i>					
50 -----	1.36	.021	346	251	.30-.42
52 -----	1.57	.023	340	217	.31-.46
58 -----	2.01	.030	375	187	.32-.40
76 -----	5.15	.090	926	180	.30-.40
75 -----	4.00	.120	970	209	.31-.42
78 -----	5.29	.215	2,888	546	.34-.44
81 -----	6.17	.309	4,231	686	.34-.44

DESCRIPTION OF GONADS AND OVARIAN EGGS

The gonads of *E. mordax* and *A. naso* are elongate, tapered posteriorly, and not fused. Both the shape and lack of fusion seem to be typical of clupeoids. Since the gonads are the last organs to develop, and because no special space is provided for them, they tend to crowd into whatever space is available. They assume the general shape of the body cavity and are contoured on one side by the body wall and on the other side by the other internal organs.

The gonads of *C. mysticetus* differ from those of the other two species in being tapered anteriorly (this species has a deeper body and a larger body cavity posteriorly) and joined posteriorly.

The gonads of *A. naso* and *E. mordax* resemble those of most fish species in that the left gonad is usually larger than the right. In *E. mordax*, the left gonad composed 49 to 62% of the total gonad weight for 29 females and 46 to 62% for 13 males; in *A. naso*, the percentages were 48 to 65 for 7 females and 50 to 60 for 6 males. The average for each of the four groups was between 55 and 56%. No data are available on the comparative size of gonads of *C. mysticetus*.

While most fish eggs are spherical, engraulid eggs are more or less oval. The length of the planktonic eggs of 10 species of engraulids from the Gulf of Panama (Simpson, 1959) ranged from about $1\frac{1}{2}$ to $2\frac{3}{4}$ times their width. Bolin (1936) described the planktonic egg of *E. mordax* as ellipsoidal, 1.23 to 1.55 mm long by 0.65 to 0.82 mm wide, with a segmented yolk, no oil globules, and no sculpturing on the membranes. The latter three characteristics were present in all engraulid eggs sampled by Simpson.

The formalin-preserved ovarian eggs of *E. mordax* are transparent and spherical up to a diameter of 0.14 mm, but larger eggs are elongate. The eggs are translucent and darker at 0.20 mm because of yolk formation, and become opaque as size and yolk content increase. The largest ovarian eggs I found were 0.86 mm long.

The eggs of *A. naso* are spherical throughout their ovarian development. Yolk begins to form in eggs of 0.10-mm diameter. The largest ovarian eggs measured 0.46 mm. Among the 14 species of engraulids examined by Peterson (1956), *A. naso* was one of three that had spherical ovarian eggs; the others had oval eggs. The egg developing within the ovary has no perivitelline space and has the same shape as the yolk. After spawning, the yolk, enclosed in the vitelline membrane, apparently retains the same shape—either spherical or more or less ovate—that it had within the ovary, but the shell of the egg becomes ovate. Among the engraulid eggs in plankton figured by Simpson (1959), some oval eggs had oval yolks and others had round yolks.

The ovarian eggs of the anchoveta are oval. Peterson (1961) reported ovarian eggs of this species up to 0.66 mm long, while Simpson found that planktonic eggs average 1.17 mm long and 0.56 mm wide.

NUMBER OF EGGS PER SPAWNING

The number of eggs per spawning is assumed to equal the number of eggs in the most advanced modal group in the ovaries. As in other fishes, the number of advanced eggs tends to increase as fish size increases. Generally the number of eggs is proportional to the weight of the fish and to the cube of the standard length. However, in many species egg production occurs over such a relatively short range of fish lengths, and variation in the number of eggs produced at each length is so great, that the relationships of length and weight to egg production are masked. As a rule of thumb, the curvilinear relationship between standard length and number of eggs produced is not apparent unless the largest fish in the sample is more than twice as long as the smallest fish.

Peterson (1961) fitted a least squares straight line to his length-fecundity data for the anchoveta, $E = 101,200 + 1.0006L$, in which E = the number of ova in the spawning mode and L = standard length in mm. His largest fish (162 mm) was only 1.4 times the length of the smallest (115 mm), and he found no indication of a significant departure from a linear relationship.

In my sample of 19 anchovies, the length of the largest fish (138 mm) also was only 1.4 times the length of the smallest fish (97 mm); the straight-line relationship is $E = 2,175 + 7.700L$. The parabolic curve based on the cube of length is $E = 0.00646L^3$, and that based on the log-log transformation is $E = 0.000574L^{3.5}$. The respective correlation coefficients are 0.816, 0.820, and 0.830, which, though highly significant, are not significantly different among themselves. If the range of lengths of the fishes could be increased, the curvilinear relationships should become progressively better than the straight-line relationship.

Although in the present samples the correlation coefficient from the log-log transformation is slightly better than that based on the cubic relation, the latter will often yield a lower variance and higher correlation coefficient. This relation also holds for the length-weight curve. The log-log line heavily weights lower numbers in its transformation, resulting in a parabolic curve that is only a rough and often misleading approximation of the best fitting curve. If spawning occurs over a restricted range of fish lengths, the straight-line relationship is practical, whereas if the length range is greater, the cubic relationship is generally satisfactory.

For some purposes, weight-fecundity relationships are more useful than length-fecundity. An understanding of weight-fecundity relationships may most easily be obtained by determining the number of advanced eggs produced per unit of fish weight. The mean numbers of advanced eggs per gram of fish were 574 for 19 *E. mordax*, 836 for 86 *C. mysticetus*, and 326 for 7 *A. naso*.

The number of eggs per g of fish does not appear to change with size of *E. mordax*; therefore, the weight-fecundity relationship may be described by $E = 574 W$ in which E = the estimated number of advanced eggs in the ovary and W = fish weight in g.

Peterson (1961) fitted a least squares straight line to his anchoveta weight-fecundity data and obtained $E = 3,304 + 927 W$. The large negative y-intercept indicates that the number of eggs is not proportional to fish weight but gradually increases with increasing fish size. A comparison of eggs per g of fish for the various sizes of anchovetas does not bear out this indication. The 13 smallest fish, 115 to 120 mm SL, have a mean of 533 eggs per g of fish (standard error of the mean = 35) and the remaining 73 fish, 121 to 162 mm SL, have a mean of 890 eggs per g of fish (standard error of the mean = 26). The number of eggs per g of fish does not change significantly among these remaining 73 fish; the mean is 927 eggs for the 13 smallest (121 to 128 mm) in this group and 874 for the 13 largest (153–162 mm). If the fecundities of these two groups are representative of the size groups in the population, it might be more practical to use the formulae $E = 533 W$ for fish up to 120 mm SL and $E = 890 W$ for larger fish.

The smaller specimens in a number of fish species have a lower fecundity, but the increase in fecundity with size tends to be abrupt rather than gradual. In *A. naso*, the five smaller specimens (50 to 76 mm) averaged 209 (180 to 254) eggs per g of fish, whereas the two larger specimens (78 and 81 mm) averaged almost three times as many, 616 (546 and 686).

Although only 19 anchovies were used to determine fecundity, the resulting data should be satisfactory for census purposes if the sample is representative of the population. Eggs per g of fish were almost identical for different areas (Santa Catalina, San Diego, San Benitos) and different seasons (March, July, September) as well as for different sizes of fish. Therefore, in spite of the small sample, I believe that it is representative of the northern anchovy population.

The mean number of eggs per g of fish, 574, has a standard error of 30. The 95% fiducial limits are ± 60 eggs per g or $\pm 10\%$. For the much larger sample of anchovetas, the 95% fiducial limits are ± 54 eggs or about $\pm 6\%$.

THE RELATION OF FECUNDITY TO THE ESTIMATION OF BIOMASS OF ADULT ANCHOVIES

To determine the biomass of the adult anchovy population from egg census data, we must know the sex ratio of the population by weight, the average number of times the population spawns during the egg census period (1 year for the present study), and the number of eggs per spawning.

Of 3,500 anchovies sampled during the 1952-53 and 1953-54 seasons (for which length and sex are available), 1,545 were males and 1,955 were females (Miller et al., 1955). The number of males equaled 79% of the number of females. The males averaged 138.5 mm SL and the females 142.2 mm SL. If we assume that there is no great difference in form between male and female anchovies then, mean SL^3 of females is to mean SL^3 of males as mean weight of females is to mean weight of males. From this we can determine that the mean weight of males was about 92% of the mean weight of females. Multiplying percentage weight by percentage numbers gives a male biomass equal to 73% of the female biomass.

Weight and sex data are available for a sample of 336 anchovies taken from the San Francisco area between September 1952 and February 1953. The 181 females averaged 149.5 mm SL and weighed a total of 6,652 g; the 155 males averaged 145.3 mm SL and weighed a total of 5,172 g, or about 78% of the total weight of the females.

From these data we may assume that the biomass of male anchovies available to the fishery equals about 75% of the female biomass. If for one spawning a female produced 574 eggs per g of body weight, 5.2×10^8 eggs would be produced per short ton of female biomass; therefore, we should expect the same number of eggs per 1.75 short tons of adult anchovies or about 3.0×10^8 eggs per ton of adult anchovies.

The number of times an anchovy spawns in one season is not known. There has been some speculation that the prespawning ratio of small yolked eggs to large yolked eggs in the ovary is an indication of the number of spawnings that will take place in that spawning season. That

is, if the ratio is approximately one to one at the beginning of the spawning season, there will be two spawnings; if it is two to one, there will be three spawnings, etc. As the spawning season progresses, the ratios would decrease by one after each spawning. This speculation is not supported, however, by my data for anchovies (nor by much more extensive unpublished data for sardines). Ratios apparently are not related to size of fish, area, or season. Ratios for individual fish ranged from 1.3:1.0 to 2.4:1.0. The mean ratios for fish in the present collections were 2.2:1.0 (San Diego, March 1951), 1.9:1.0 (San Diego, March 1960), 1.7:1.0 (Santa Catalina Channel, July 1953), and 1.8:1.0, (San Benitos Islands, November 1952).

The anchovy with the 2.4:1.0 ratio was most nearly ripe, and had eggs up to 0.86 mm long. It was also the only fish that exhibited a distinct trimodal distribution of yolked egg sizes. The ratios of the numbers of eggs in each mode, from smallest eggs to largest, were 1.4:1.0:1.0. If the largest eggs were omitted, the remaining distribution would closely approximate the lower ratios in anchovies in which eggs in the most advanced group were smaller. In addition, a number of the female anchovies examined could not be used for fecundity estimates because they contained only small, yolked eggs with a unimodal size distribution. The eggs in a few of these fish appeared to be undergoing resorption.

The ovaries offer no evidence of a fixed number of spawnings. The egg ratios suggest that the anchovy may spawn one, two, three, or more times per year; the eggs remaining after a given spawning might either be resorbed or be replenished from the reserve of non-yolked eggs. If replenishment does occur, the ratios are even less meaningful.

In 19 anchovetas, the eggs in the advanced mode averaged more than three times as many as the smaller yolked eggs (Peterson, 1961). Howard and Landa (1958) noted the paucity of smaller eggs in this species and concluded that only one batch of eggs was spawned, following which the smaller eggs were resorbed. The short spawning season of the anchoveta also supports the idea of a single spawning. Almost all anchoveta eggs taken in plankton tows in the Gulf of Panama were collected in November and December, and neither eggs nor ripe fish could be found from mid-January to October (Simpson, 1959).

In *A. naso*, ratios of small yolked eggs to large yolked eggs ranged from 0.0:1.0 to 4.2:1.0. Fish with developing ovaries have been taken in Costa Rica in August, September, and January (Peterson, 1956), and my two samples from Baja California were taken in July and November. A protracted spawning season and multiple spawning are indicated.

The spawning season of the northern anchovy also is protracted; some spawning occurs in every month, and fish with developing ova may be found at any time of year. Nevertheless, there is a definite annual peak in spawning, as shown by the number of anchovy larvae taken in plankton tows off the California and Baja California coasts during the 7 years 1951 through 1957 (Ahlstrom, 1953, 1954, 1958, 1959; Ahlstrom and Kramer, 1955, 1956, 1957). Peak spawning occurred in March (4 years), February (2 years), and January (1 year), and spawning during the peak month included 20 to 33% of the total spawning for each year.

During the early part of the year, almost all of the mature females in the population contain well-developed eggs or are recently spent; consequently, later spawnings must represent repeat spawnings by at least part of the population, although younger, late-maturing females may contribute. If the average time required to mature a second batch of eggs after spawning of the first batch was one month, if all adult females spawned in the peak month, and if 20 to 33% of the year's spawning took place in the peak month, an average of three to five spawnings per year would be indicated. The percentage of annual spawning ranged from 34 to 49 for the 2 consecutive highest months over the 7-year period. If the spawning interval were 2 months, an average of two or three spawnings would be indicated.

The hake, *Merluccius productus*, which occurs in the same area and has a peak spawning period very similar to that of the anchovy, spawns only once a year (MacGregor, 1966). Larval occurrence indicates that 18% of the hake spawning takes place in January, 36% in February, 35% in March and 10% in April, with the remaining 1% scattered through the next 8 months. The percentage of hake spawning for the four peak months is about double that of the anchovy. If egg development and spawning are otherwise similar, but the hake spawns only once a year, we might postulate that the anchovy spawns an average of twice a year.

If one spawning produces 3×10^8 eggs per short ton of spawning fish, two spawnings would produce 6×10^8 , three spawnings 9×10^8 , and four spawnings 12×10^8 eggs per ton. If we arbitrarily estimate the average number of spawnings a year to be two and a half, and the actual number was only one, then the actual biomass would be 250% of our estimated biomass; if the actual number of spawnings was two, actual biomass would be 125% of that estimated; if three, 83%; and if four, 63%. Not knowing the average number of spawnings per year can introduce considerable error into the calculations.

The number of eggs spawned per unit of fish weight for one spawning and biomass ratio by sex probably change so little from year to year that data obtained in one year could be used for any other year. The number of spawnings, however, could change from year to year, depending on the size composition of the spawning stock or on hydrographic conditions. Another factor affecting calculations would be the change in biomass that results from the maturation of juvenile fish and mortality of adults during the year. Biomass estimates would be an annual mean value weighted to heaviest periods of spawning.

Probably a better way to estimate the adult population on the basis of egg counts would be to sample intensively during a period of peak spawning. If we could determine, by sampling, that portion of the adult population which had spawned once during one or two of the peak spawning months of a given year, we could calculate the average biomass existing at that time from an egg census covering the same period. This procedure largely would eliminate problems arising from weighted annual biomass estimates, multiple spawning, and changes in number of spawnings from year to year.

SUMMARY

The number of advanced eggs produced per unit of fish weight was 574 eggs per g of female for *E. mordax*, 836 for *C. mysticetus*, and 326 for *A. naso*. Although the number of eggs per gram of fish did not change with size of fish for *E. mordax*, it was considerably higher for larger specimens of each of the other two species.

The biomass of male anchovies in California commercial landings equaled about 75% of the biomass of females. Therefore, on the basis of one spawning, 3.0×10^8 eggs would be produced per short ton of spawning adult anchovies. The number of times a female anchovy spawns in a season cannot be determined from presently available data.

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SUMMER WATER REQUIREMENTS OF DESERT BIGHORN IN THE SANTA ROSA MOUNTAINS, CALIFORNIA, IN 1965¹

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A survey was made in 1965 to obtain a better understanding of desert bighorn (*Ovis canadensis*) dependence upon water in the Santa Rosa Mountains during the summer. Twenty bighorn were marked at one spring by using Hansen's dye spraying device. The nontoxic dye could be seen on the horns of the sheep for 1½ months. Many of the ewes, lambs, and young bighorn stayed within three-quarters of a mile of waterholes during July and August. Rams in their prime or older traveled as far as 3 miles from water and made fewer trips to water during July and the first half of August. Optimum water distribution is at intervals of 2 miles. Bighorn waterhole count data are evaluated.

INTRODUCTION

A primary factor limiting bighorn sheep populations in the Santa Rosa Mountains of California is lack of water. Jones, Flittner, and Gard (1957) found that bighorn were restricted to within 1 mile of water during the summer. The present study was conducted to obtain more information on summer movements, frequency of trips to water, and distance traveled to water. It was also hoped to get a better evaluation of the waterhole counts regularly conducted by the Department of Fish and Game.

The desert slopes of the Santa Rosa Mountains above Palm Desert, Riverside County, are ideal for such a study because of the convenient location of roads, which made it possible to cover much of the study area on foot in 1 day. We had a good knowledge of the summer bighorn concentration areas.

METHODS AND PROCEDURE

A dye spraying device for marking bighorn, developed by Hansen (1964) and improved upon by Simmons and Phillips (1966), was installed at the upper spring in Carrizo Canyon above Palm Desert. The sprayer was installed by the first of May to allow the bighorn time to become accustomed to it. American Cyanamid Company's Calcoacid Blue AX Double Dye was used. This nontoxic dye was mixed in a 50% solution of isopropyl alcohol. The lower spring and a water trough in Carrizo Canyon were covered with brush from June 22 to July 13 to force the bighorn to come to the upper spring to be marked. Bighorn were marked from June 29 to July 10. After marking was completed, the brush was removed.

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An effort was made to learn how often the sheep came to drink during three 5-day periods between June 28 and July 24. A search was made to locate marked bighorn at least 2 days of every week in July and the last 3 weeks in August. Several days in September were spent locating bighorn in the study area.

The Department's annual bighorn waterhole count, held July 7 to 10, provided a check on the movement of these marked sheep. The count covered 10 waterholes. Participants in the count were members of the U.S. Forest Service, California Department of Parks and Recreation, U. S. Bureau of Land Management, U. S. Bureau of Sport Fisheries and Wildlife, University of California, and the University of Redlands.

Weather records were obtained from the University of California Desert Laboratory, at the mouth of Deep Canyon (Table 1). We recorded air temperatures at the upper spring in Carrizo Canyon. On-site temperatures were approximately 2 F cooler than the maximums recorded at the Desert Laboratory.

RESULTS OF THE MARKING OPERATION

We intended to mark all of the bighorn that came to Carrizo Spring. However, at least nine bighorn came to the spring and drank without being marked. This was partly due to operating difficulties with the spray gun on July 7.

The marking device worked well. Excessive mechanical noise was eliminated by assembling the marking device so that the solenoid plunger did not hit the head of the chamber.

Twenty bighorn were marked; seven were sprayed twice with dye. One ewe was not marked because a conspicuous hole in the horn was sufficient for identification. The first two bighorn marked appeared less reluctant to kneel under the marking gun than those that followed. Later they knelt to drink uneasily, especially if there was wet dye on the ground.

The dye faded considerably on the hair within 10 to 16 days, but remained clearly visible on the horns. Most of the bighorn were shedding when they were marked. It rained on July 17 and 18, washing some of the dye off the bighorn. By this time it was obvious that the dye was retained best on the horns.

By August 18 there had been 2 days of fairly heavy rain and 6 days of light showers in the area. Rain faded the water-soluble dye rapidly. Forty-five days after marking, the dye was difficult to see on the horns with a 20-power spotting scope, and was not visible on the hair. By the end of August, the dye was gone.

Summer Population Density

With the aid of the 20 marked sheep and observations on sex, horns, and other physical characteristics, we were able to get a count of 33 individual bighorn in Carrizo Canyon during the marking period. Sex and age ratios of the 33 bighorn classified by the first week of July were 100 ewes; 84 rams; 46 lambs; 23 yearlings.

Within the concentration area of $4\frac{1}{2}$ square miles in the Carrizo drainage and adjacent ram area (Figure 1), there were at least seven bighorn per square mile in July and August.

TABLE 1
**Weather Records Obtained From the University of California Desert
 Laboratory, Located at the Mouth of Deep Canyon**

	Daily Temperature (F)							
	June		July		August		September	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1.....	72	58	100	72	103	80	94	70
2.....	78	54	105	76	102	79	93	71
3.....	84	58	106	86	104	78	94	78
4.....	88	60	108	84	101	75	90	74
5.....	92	64	103	83	102	80	84	68
6.....	92	65	106	80	102	86	81	70
7.....	79	66	105	81	97	81	82	63
8.....	76	68	99	75	94	78	88	60
9.....	88	55	95	74	105	81	92	73
10.....	91	64	97	75	96	83	94	74
11.....	98	68	96	71	91	79	92	69
12.....	94	71	97	70	95	78	93	68
13.....	91	67	95	71	100	85	96	73
14.....	84	63	96	79	92	78	101	76
15.....	75	63	96	82	94	76	103	77
16.....	74	61	98	80	95	80	86	73
17.....	80	56	94	80	90	78	76	62
18.....	85	62	94	74	95	74	72	63
19.....	88	61	98	79	92	73	70	58
20.....	91	67	99	72	96	78	83	57
21.....	92	67	98	72	94	78	86	68
22.....	91	65	94	71	92	68	92	65
23.....	89	64	97	76	94	68	96	78
24.....	89	64	97	77	97	70	94	78
25.....	81	63	96	71	98	76	91	69
26.....	80	56	98	72	100	78	91	68
27.....	92	63	101	70	97	78	85	63
28.....	95	73	102	84	102	81	77	63
29.....	96	73	92	76	103	87	79	61
30.....	97	76	94	74	97	74	84	67
31.....			103	78	96	73		

Precipitation (inches)

June	July	August	September	October
	17.....0.32	7.....0.52	6.....0.05	
	18.....0.27	11..... T		
	29.....0.05	16.....0.32		
Total.....0.00	Total.....0.64	Total.....0.84	Total.....0.05	Total.....0.00

It rained hard in Carrizo Canyon on August 16. Showers which fell over Carrizo Canyon on August 14, 15, and 17 were not recorded at the mouth of Deep Canyon.

Frequency of Trips to Water

After June 27, the weather turned hot (Table 1). On June 29, the bighorn started coming regularly to the upper spring in Carrizo Canyon. Some of these bighorn came to the spring nearly every day during the 12-day marking period, but they did not drink on each trip to the spring. Possibly some of the ewes and young sheep did not drink

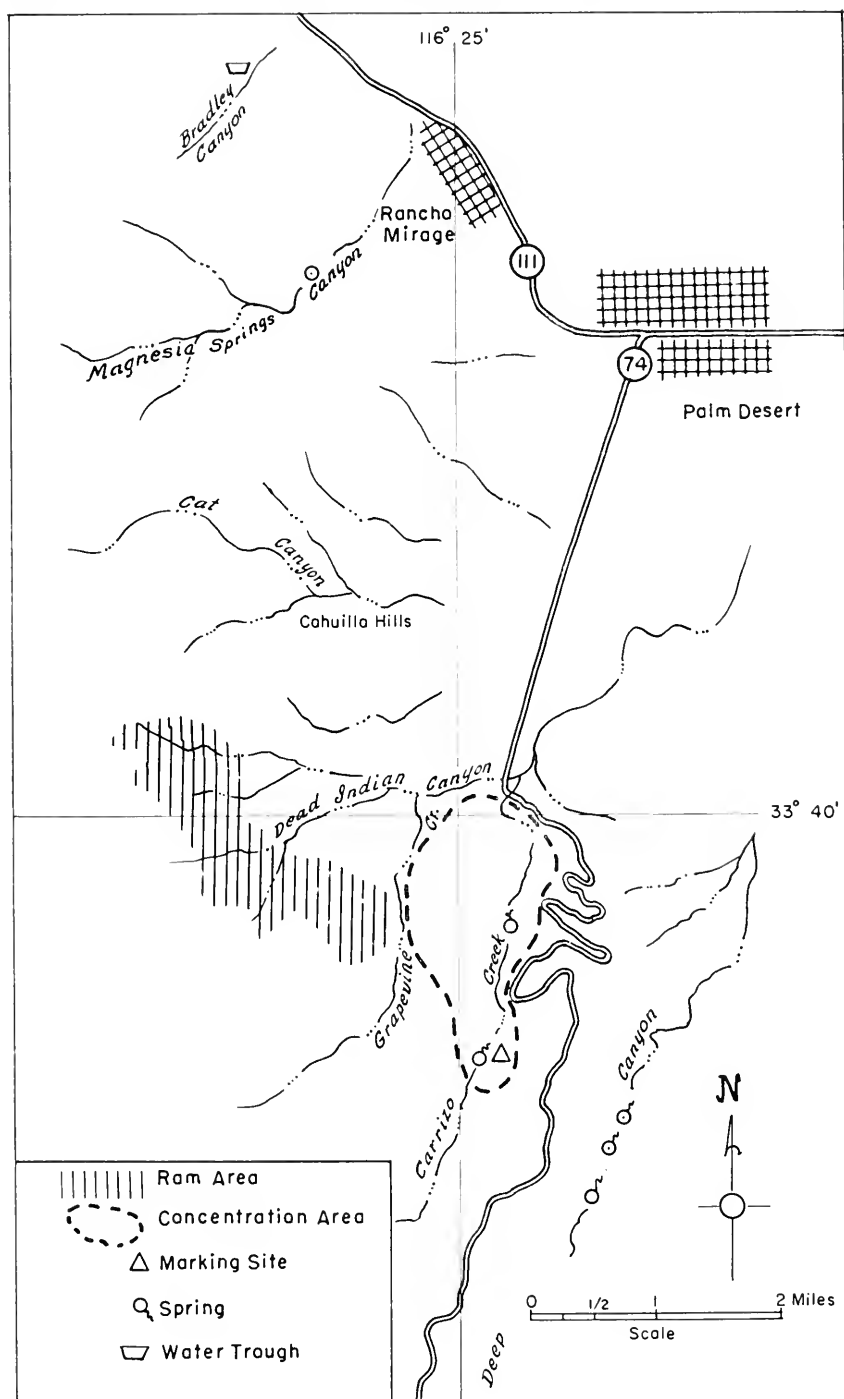


FIGURE 1—Map of the study area in the Santa Rosa Mountains, Riverside County, showing the location of the summer concentration area in 1965.

on one or two of the trips to water because of disturbance caused by the marking.

Following 5 hot days (July 2-6), with the temperature reaching 102 to 104 F in the shade, there were 21 bighorn at the spring for 2 days in succession. Most of these drank at least once during the 2 days. Fortunately, by this time we had marked most of these sheep, so that they could be identified. On July 9, the weather turned slightly cooler, with maximums in the 90's. Only three ewes and one mature ram came to the spring on July 10.

Between July 20 and 23, we were able to locate most of the marked bighorn. During this period they followed about the same pattern of travel and drinking as they did between June 29 and July 9.

Some of the ewes and lambs took a drink 5 or 6 days of the 12 days that they came to the spring. Twice ewes came to water without their lambs. One- and 2-year-old rams usually accompanied the ewes and lambs to the spring and drank about as frequently as the lambs. Prime and older rams did not water in July as often as the ewes with lambs. Water was available in potholes during much of August because of frequent showers. After these rains had produced new growth on the vegetation, the bighorn made fewer trips to the waterholes.

Welles and Welles (1961) reported that bighorn in Death Valley drank every day if near water, but 1 to 3 full days without watering were common. Our brief survey indicated yearlings and ewes with lambs visited a waterhole daily or every other day in hot, dry weather.

Area Used by Bighorn During the Summer

It is 6 miles from Carrizo Canyon to Magnesia Spring, the nearest waterhole to the north in bighorn habitat. It would take a strong man 1 day to make this hike over the same route that a bighorn would travel. The nearest springs from Carrizo Canyon to the south are in Deep Canyon, $1\frac{1}{4}$ miles southeast of Carrizo Spring.

We did not find any sign that the bighorn of Carrizo Canyon traveled to Deep Canyon in July and August 1965. However, we have seen bighorn travel this route in other summers.

During the July and August observation periods the ewes, lambs, and young rams were observed to stay within three-quarters of a mile of the waterholes in Carrizo Canyon. Most of the time the bighorn stayed within a half-mile cruising radius of a spring during the hot summer period. The longest distance ewes and young bighorn traveled in 1 day was $1\frac{1}{2}$ miles. Most of the time they covered less ground. Rams traveled as far as 3 miles from water during July and the first 2 weeks in August. After the middle of August, the beginning of the rutting season, the rams stayed nearer the waterholes.

We have observed a similar pattern of bighorn distribution between Cat Canyon and Highway 74 (Figure 1) in other summers. Jones et al. (1957) found the same bighorn distribution during the summer of 1953 in Carrizo Canyon as we did in 1965.

DISCUSSION

Water Distribution

Carrizo Canyon ewes and lambs ranged up to three-quarters of a mile from water during the summer of 1965. Rams range over a much larger area and make fewer trips to water. Adequate water distribution in suitable habitat is at intervals of $1\frac{1}{2}$ to 2 miles in the Santa Rosa Mountains. Where springs are located 2 miles or less apart in these mountains, we have observed bands of bighorn traveling from one spring to another in the summer.

Water Development

Most of the springs in the bighorn habitat of these mountains have been developed. There are five waterless areas on the desert slopes of these mountains that are used by a few rams during the summer. To provide water for ewes and young bighorn in these areas would require installation of rain catchment devices. Helicopters could be used to move equipment into the development area.

Human inroads upon the bighorn habitat in Magnesia Canyon in 1964 and 1965 provided an important sidelight on future water development and bighorn management. In March 1954 a tank was blasted out of a rock face below the Magnesia Spring seep by the Department of Fish and Game (Weaver, Vernoy, and Craig, 1959).

In years when there was water in this tank, bighorn used it heavily during the summer. This waterhole is now about 1 mile from a residential area. Vandalism of the tank and year-round picnicking at this location in 1964 and 1965 discouraged bighorn from using this waterhole. No bighorn tracks were found at this waterhole in July or August of 1965. Bighorn that formerly drank at Magnesia Spring went to a water trough recently constructed in Bradley Canyon, where they were not disturbed. This trough, built by local residents, is located $1\frac{3}{4}$ miles north of Magnesia Spring.

This incident shows that bighorn avoid water where there is repeated human disturbance, and demonstrates that the animals readily adapt to a new water source.

Evaluation of the Waterhole Counts

The Department has conducted bighorn waterhole counts in the Santa Rosa Mountains since 1958, with the exception of 1960 (Blong, 1965). These counts have been held for 3 to 4 days at eight waterholes when the weather first turns hot in the summer. The principal objectives were to record population trend, sex ratios, and age composition. A better evaluation of previous counts is made possible by experience gained from the marking study.

Waterhole counts must be held at the same time each year, in the same areas, and for the same period of time to obtain accurate information. The waterholes should be representative of the entire mountain range. Bighorn behavior should be taken into account. A more complete count is obtained if it is held during extremely hot weather. We know that some bighorn water on bright moonlight nights and rams often drink at dawn.

In measuring population trend, the waterhole count has two factors for error that oppose each other. One is duplication, which applies mostly to ewes and young bighorn. This error becomes greater each day of the count. The other factor is that some of the bighorn may not visit the waterholes from 4 to 8 days. The longer the waterholes are watched, the greater the opportunity to observe most of the local population as well as bighorn from nearby waterholes. In these mountains, 3 days of counting appear to be adequate for lamb survival information as well as to detect major fluctuations in the population. This length of time also minimizes duplication. Some of the bighorn using the waterholes may escape observation but when counts are made for a number of years they provide an index to the relative abundance of bighorn in the mountain range.

Very likely more than 33 bighorn lived in Carrizo Canyon and the adjacent ram area in the summer of 1965. A few rams that were not seen during the counting period were in the area later in the summer. Rams characteristically travel from one waterhole to another during the summer (Welles and Welles, 1961; Simmons, 1964). It appears that 33 is close to the maximum number of bighorn that water in Carrizo Canyon. The largest number of bighorn counted during a previous waterhole count in Carrizo Canyon was 27. Jones et al. (1957) recorded 26 bighorn for the Carrizo drainage in 1953.

SUMMARY

A survey was made in 1965 to obtain a better understanding of desert bighorn dependence upon water in the Santa Rosa Mountains during the summer. Twenty bighorn were marked in a 12-day period at one spring by using Hansen's dye spraying device. This made it possible to identify 33 bighorn in the summer concentration area. The nontoxic dye could be seen on the horns of the sheep for 1½ months. Many of the ewes, lambs, and young bighorn came nearly every day to the waterholes before the summer showers occurred. During July and August the ewes, lambs, and young bighorn stayed within three-quarters of a mile of the waterholes. Rams in their prime or older traveled as far as 3 miles from water and made fewer trips to water during July and the first half of August.

Adequate water distribution for bighorn in the Santa Rosa Mountains is at intervals of 2 miles.

A clearer insight was obtained into such problems as duplication and frequency of trips to water that complicate the evaluation of bighorn waterhole count data.

ACKNOWLEDGMENTS

It would have been impossible to properly watch the waterholes and search the area for bighorn without the assistance of William Asserson, Edmund Green, William Sproul, and Robert Vernoy of the Department of Fish and Game and John Lively of the U. S. Forest Service.

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THIRD COOPERATIVE SURVEY OF THE CALIFORNIA CONDOR¹

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The third annual California condor (*Gymnogyps californianus*) survey was conducted October 17 and 18, 1967. One hundred fifty sightings were reported from 19 of 67 stations manned on October 17, 1967. Seventy-five sightings were reported from 21 of 68 stations manned on October 18, 1967. These sightings, by an evaluation of field reports, were reduced to a minimum count of 46 and 33 individual birds, respectively, for the 2-day survey. A decrease of 5 birds on the first day of the 1967 survey from the count of 51 birds during the 1966 survey does not necessarily indicate a decrease in the condor population. The evaluation procedures have been the same through all three annual surveys, and results are conservative minimum population counts. The actual condor population is in all probability greater than the minimum population figure arrived at in the survey.

INTRODUCTION

The first cooperative survey of the California condor was conducted in October 1965 (Mallette and Borneman, 1966) and the second in October 1966 (Mallette et al., 1967). The survey procedures are coordinated by a Condor Survey Committee representing the California Department of Fish and Game, U. S. Fish and Wildlife Service, U. S. Forest Service, National Audubon Society, University of California, and other conservation interests.

Objectives of the survey are to: (i) establish periodic condor population counts which will provide an index to the population; (ii) gain an indication of nesting success based on the age classification of birds observed; (iii) obtain more information on the distribution of condors; (iv) foster public awareness of the precarious status and problems related to the protection of the species; and (v) gain other knowledge of condors and raptors as incidentally provided by such survey.

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² Prepared for and with approval of the Condor Survey Committee: Chairman Ben Glading, Chief of Wildlife Management Branch, California Department of Fish and Game; A. Starker Leopold, Professor of Zoology, University of California; William P. Dasmann, U. S. Forest Service; Clinton H. Lostetter, U. S. Fish and Wildlife Service; John C. Borneman, National Audubon Society; Fred C. Sibley, U. S. Fish and Wildlife Service; and Robert D. Mallette, California Department of Fish and Game.

METHODS

The methods and evaluation procedures were essentially as reported for the 1965 and 1966 surveys (Mallette and Borneman, 1966; Mallette et al., 1967). Changes in the 1967 survey involved minor shifts in station locations and the establishment of survey headquarters in Bakersfield. The evaluation procedures and philosophy are described in more detail in the discussion section.

WEATHER

The weather on both days was fair and warm, with mainly easterly winds of 10 to 15 miles per hour. Except for increased haze causing reduced visibility the afternoon of October 18, observers reported little difference in conditions between the two days. The Timber Canyon fire, located in Ventura County at the lower edge of the condor range, caused abandonment of several stations, and the smoke restricted visibility at a few other stations. Table 1 presents weather conditions at five stations, for comparison with conditions in other years.

TABLE 1
U.S. Forest Service Lookout Stations Reporting Weather Information
Which Were Also Condor Survey Stations

Readings Were Taken 2 p.m. October 17 and 18, 1967

October 17					
Lookout station	County	Average wind velocity (miles per hour)	Direction of wind (from)	Temperature (F)	Relative humidity
Thorn Point.....	Ventura.....	6	S	72	4
Nordhoff.....	Ventura.....	6	SE	81	9
McPherson.....	Santa Barbara.....	8	SW	74	9
Figueroa.....	Santa Barbara.....	6	W	84	6
Hill Mountain.....	San Luis Obispo.....	10	NW	80	11
October 18					
Thorn Point.....	Ventura.....	9	SE	69	11
Nordhoff.....	Ventura.....	8	SE	78	13
McPherson.....	Santa Barbara.....	2	NE	69	20
Figueroa.....	Santa Barbara.....	6	S	87	9
Hill Mountain.....	San Luis Obispo.....	8	NW	80	13

RESULTS

During the survey 69 stations were manned by 130 observers. On October 17, 150 condor sightings were reported from 19 stations. These sightings, by an evaluation of the reports, were reduced to 46 individual condors. The age classification breakdown was 3 juveniles, 1 immature, 4 subadults, 30 adults, and 8 unknown. An estimated 1,287 raptors of 11 species were also reported on the first day of the survey (Table 2).

TABLE 2

Raptors Reported During Condor Survey October 17-18, 1967

Species	Date reported	
	Oct. 17	Oct. 18
Turkey vulture, <i>Cathartes aura</i>	906	1,206
Golden eagle, <i>Aquila chrysaetos</i>	77	67
Bald eagle, <i>Haliaeetus leucocephalus</i>	1	0
Sharp-shinned hawk, <i>Accipiter striatus</i>	25	20
Cooper's hawk, <i>Accipiter cooperii</i>	29	38
Red-tailed hawk, <i>Buteo jamaicensis</i>	122	225
Swainson's hawk, <i>Buteo swainsoni</i>	11	71
Rough-legged hawk, <i>Buteo lagopus</i>	3	2
Pigeon hawk, <i>Falco columbarius</i>	1	3
Sparrow hawk, <i>Falco sparverius</i>	67	57
Prairie falcon, <i>Falco mexicanus</i>	0	1
Marsh hawk, <i>Circus cyaneus</i>	2	8
Miscellaneous raptors.....	43	51
Totals.....	1,287	1,749

On October 18, 75 condor sightings were reported from 21 stations. By an evaluation of the reported sightings, 33 individual condors were seen. The age classification breakdown was 2 juveniles, 4 immatures, 1 subadult, 23 adults, and 3 unknown. The observers also reported an estimated 1,749 raptors of 11 species (Table 2).

The details of individual sightings have not been included in an appendix, as was done for the 1965 and 1966 surveys. Copies of the supporting data are available for review at the office of the California Department of Fish and Game, 1416 Ninth Street, Sacramento, California. Observation station locations and sighting success are plotted in Figure 1.

DISCUSSION

During the past year many questions have been asked concerning interpretation of the survey results. Some of these reflect a considerable misunderstanding of the purpose of the survey and its evaluation and results. A discussion of these aspects has therefore been included in this paper.

The condor survey was initiated to develop methods of quickly detecting significant changes in the condor population. The methods used by Koford (1953) and Miller, McMillan, and McMillan (1965) give population trends over a long period and are not applicable to an annual population survey. The cooperative condor survey is still in an experimental stage, and results are not yet comparable. Although not yet indicating changes in population, the results have confirmed a minimum population figure higher than previous estimates. The survey is essentially a simultaneous count of condors, and the resultant figure may be considered the minimum number of condors still in existence. The 1967 count may be correctly quoted only as 46 plus, not as 46 plus or minus.

Survey methods have been described by Mallette and Borneman (1966) and will only be reviewed here. Rapid reporting of sightings

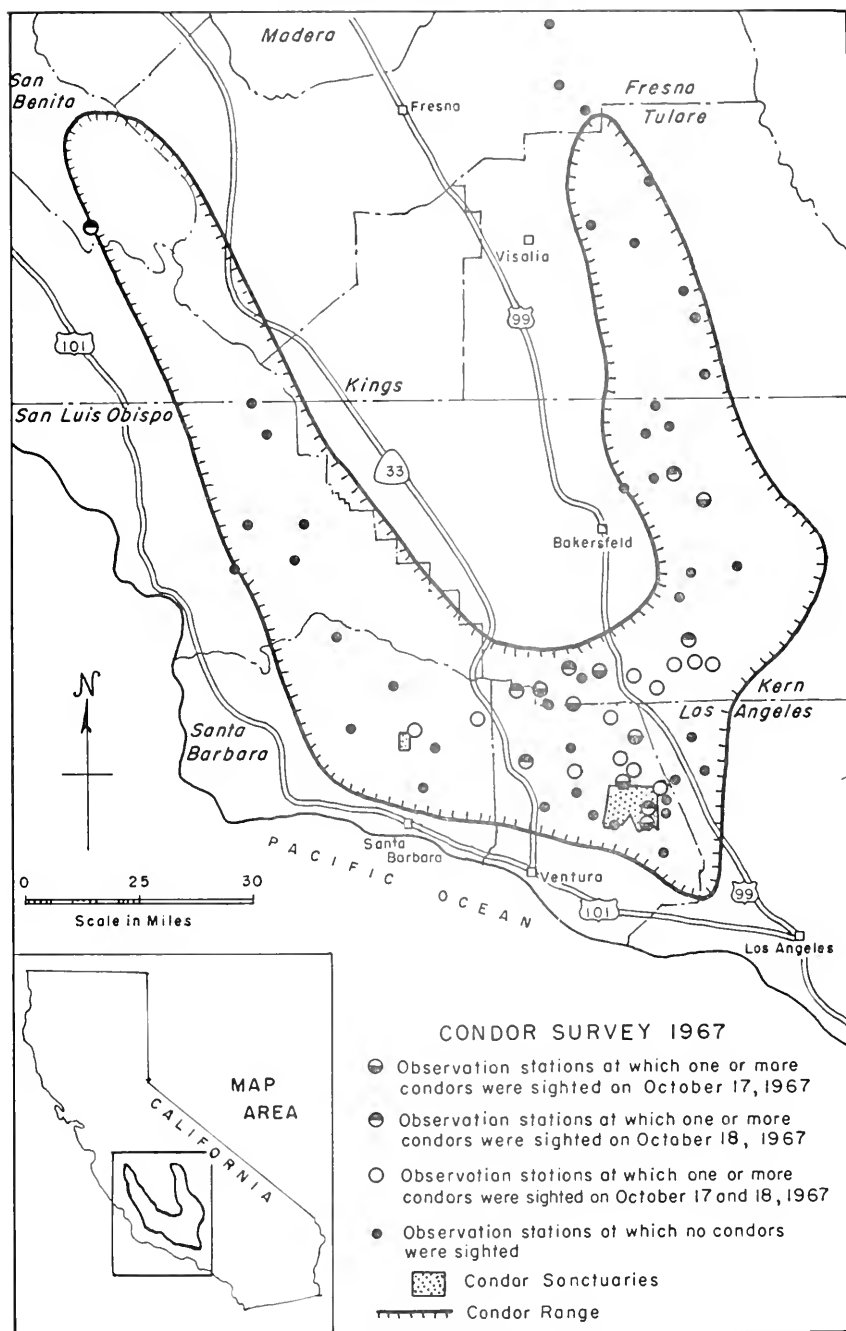


FIGURE 1—Locations of condor survey observation stations and sightings on October 17 and 18, 1967. Drawing by Cliffa Corson.

from observation stations is essential for efficient evaluation of survey data. Sighting reports are phoned in the same day as made, and all missing or questionable reports are checked by the day after the survey. Visual presentation of data was accomplished by using a mosaic of topographic maps covering the condor range. Arrows were placed on the map in the appropriate places for all sightings, and color coded for age and for morning or afternoon sightings. This visual layout allows for comprehension and rapid reanalysis of data not possible from reading the observation report forms. In analyzing sighting reports, cards for individual sightings are arranged chronologically and analysis is started with the earliest sighting.

A condor "sighting" is defined as a reported observation of one condor at one observation station. The same bird seen simultaneously from another station would be an additional sighting; five birds seen simultaneously at one station would represent five sightings.

Criteria for separation of sightings, as on previous surveys, are: simultaneous sightings, nonsimultaneous sightings at stations separated by a distance greater than a condor can cover in the time difference between the two sightings, age difference, plumage difference, and groupings of condors.

Some condors may be seen more than once, but determining which ones are seen a second time is difficult. A conservative approach is used in matching sightings to produce the minimum number of individual condors that could provide the total number of sightings (see Mallette and Borneman (1966) for further discussion).

Some critics have believed that, despite the conservative evaluation approach, limitations of the survey method have introduced serious errors in the final total. These limitations are incomplete observer report forms, limited area coverage, and human error. The effect of human error on the final count is slight. The other limitations listed tend to produce lower rather than higher counts. Observer error in identifying condors or incorrectly aging condors has been minimized by training all observers, utilizing more experienced observers on productive stations, and recruiting observers from previous years' surveys. Observers are instructed to report only those condors they are sure of and to report condors as "age unknown" if they have any uncertainty about age.

On each of the three surveys additional condor sightings, representing one or more condors unaccounted for in the survey, have been reported by nonsurvey observers. These have not been included because the final survey count is an index and not a total count. The count secondarily represents a minimum population figure, but this figure has not been projected to a total population estimate. A mistaken impression of the survey's purpose has resulted because this minimum population figure has exceeded previous estimates of the total population.

We have little to add to the discussion of the 1966 survey results (Mallette et al., 1967). The condors continue to concentrate on the Tejon Ranch in south central Kern County and have the same distribution pattern as in other surveys. On October 17, 1967, approximately 60% of the birds were east of U.S. Highway 99, 30% were in the area between U.S. Highway 99 and State Highway 33, and 10% were west

of State Highway 33. On the 2-day survey eight and seven young birds were seen, respectively. Based on survey report information, at least 11 different young were observed. This is approximately 25% of the count, indicating a satisfactory proportion of young to adults, although the figure is lower than last year.

RECOMMENDATIONS

Three recommendations for improving observer training are:

1) *Training sessions on procedures should be held immediately before the survey*—National Audubon Society members and volunteer co-operators on the preceding Saturday, state and federal agency personnel on the preceding Monday. Lookouts and other individuals unable to attend training sessions should be contacted during the preceding week.

2) *A week of condor identification sessions should be held in August on Mt. Pinos, with each observer attending one day.* This allows for smaller groups and individual training.

3) *Captains' training sessions should be held separately from observer sessions.* At this time captains could submit recommendations for changes in station location to provide better coverage, easier access, etc.

The survey has five objectives; but one of these, establishment of condor counts to provide an index of the population, has not been fully accomplished. The present survey does provide much comparable information and should be maintained. Modifications should be tested in extra experimental surveys and only changes of proven value added to the present system. Two possible subsurveys are:

1) *Establishment of bait stations to concentrate condors in view of observers.* A trial survey with five or six stations should be tried in May 1968 and another trial survey should be tried within a few days after the annual survey. The location of bait stations in this latter trial survey should be based on condor distribution as found during the annual survey.

2) *Development of a population index based on concentrated coverage of a smaller portion of the total condor range.* Additional observation stations should be established on the Tejon Ranch during the survey, their location being determined by a week of observation just before the survey. The sightings from these additional stations should be analyzed separately from the total survey results; a comparison between results would indicate any value additional stations may provide.

ACKNOWLEDGMENTS

The Condor Survey Committee wishes to thank all of the persons who participated in the condor survey; without them this survey would have been impossible. The return of many persons who participated in the first two surveys added much to the reliability of the survey results. The continued cooperation of the National Audubon Society, U. S. Forest Service, U. S. Fish and Wildlife Service, California Department of Fish and Game, California Division of Forestry, Sequoia National Park, and interested ranchers and conservationists is greatly appreciated.

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NOTES

HARBOR SEAL CENSUSES IN HUMBOLDT BAY DURING 1966 AND 1967

The harbor seal, *Phoca vitulina*, occurs along the west coast of North America from arctic Alaska to northern Baja California. Humboldt Bay is one of the principal areas frequented by the harbor seal in northern California.

For two years I conducted censuses, from winter until early summer, of the harbor seals inhabiting south Humboldt Bay (Figure 1). Counts were made using a tripod mounted 15-to-60 variable powered spotting scope from high observation points overlooking the mudflats in the bay. The seals were counted in hauling areas on the mudflats exposed during low tides. All the hauling areas were adjacent to water-filled channels, which provided the seals protection and access to food. Kenyon and Rice (1961) found that a knowledge of the hauling habits of sea lions was helpful in making more accurate population counts. This was also the case with harbor seals, since the greatest numbers of animals were observed during the afternoon low tides when it was sunny and clear.

The counts steadily increased from winter until late spring, reaching a peak during May, when the largest numbers of adults and sub-adults were counted in the Bay (Table 1). The first pups appeared during the month of April.

TABLE 1
Humboldt Bay Harbor Seal Counts, 1966-1967

1966		1967	
Date	Number	Date	Number
January 15	65	January 6	42
February 3	82	February 5	75
February 5	17 rain	February 20	86
February 18	55	March 4	53
March 1	96	March 21	98
March 13	101	April 2	120 plus 2 pups
April 10	110	April 18	113 plus 3 pups
April 22	118 plus 4 pups	April 30	132 plus 6 pups
May 1	150 plus 6 pups	May 2	205 plus 8 pups
May 13	286 plus 10 pups	May 17	285 plus 6 pups
May 30	291 plus 10 pups	May 31	308 plus 12 pups
		June 27	282 plus 10 pups

Aerial counts in both south and north Humboldt Bay steadily declined from a high of 210 on July 8 to zero on December 29, 1967 (Daniel W. Gotshall, California Department of Fish and Game, pers. comm.).

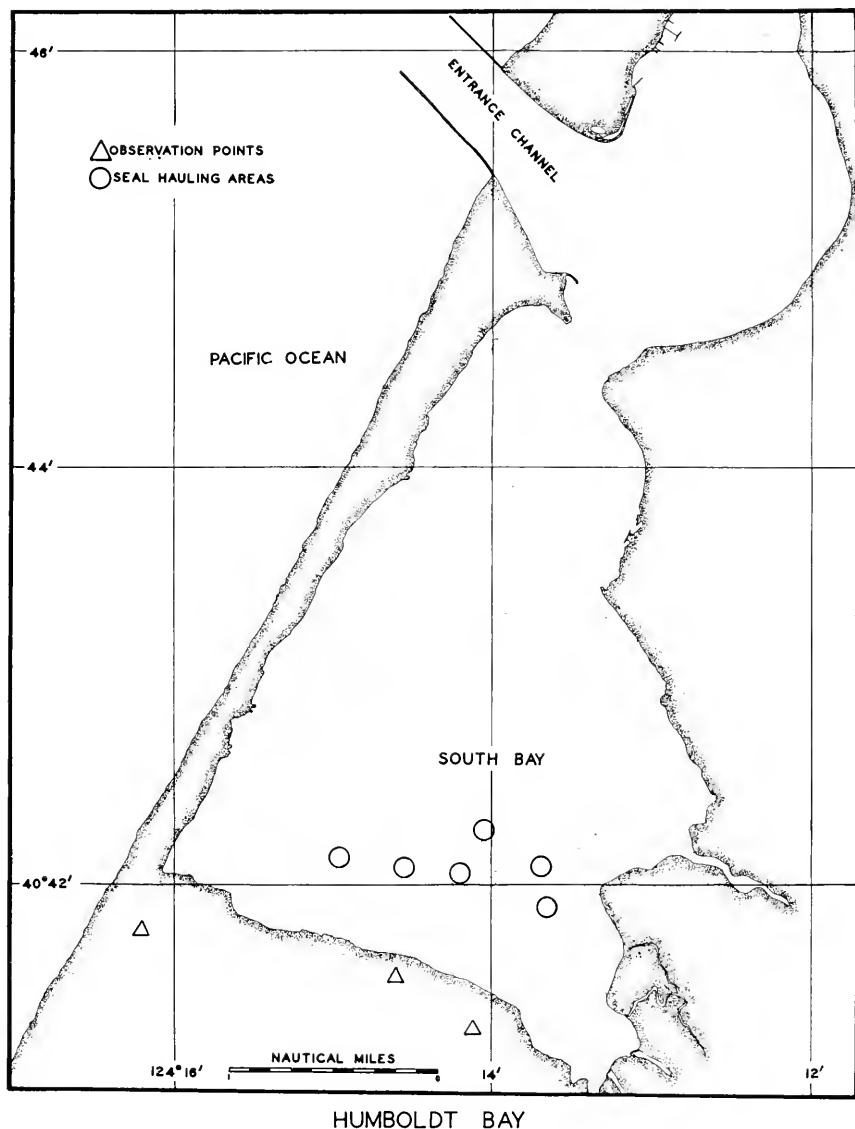


FIGURE 1—Observation points and seal hauling areas in south Humboldt Bay.

Humboldt Bay appears to be one of the major pupping grounds in northern California, and censuses should be conducted periodically to assure proper management of the harbor seal in that region.

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DEFORMED LATERAL LINE IN A JACK MACKEREL, *TRACHURUS SYMMETRICUS* (AYRES)

While taking a routine sample of jack mackerel from the purse seiner *S. Restituta II*, I observed a specimen with a deformed lateral line on its right side (Figure 1). The fish, 167 mm FL, appeared normal in other respects. It was caught during the night of April 13, 1967, in one of two 15-ton "sets" made on the west side of San Clemente Island.

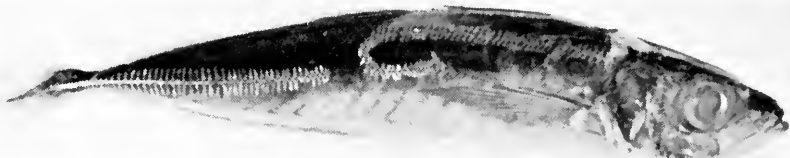


FIGURE 1—Jack mackerel with a deformed lateral line. Photograph by Jack W. Schott.

The lateral line starts normally but instead of curving downward and continuing posteriorly it curves down, forming a **U**, and continues anteriorly for a distance of 18 mm. Eight mm from the posterior end of the **U**, the lateral line recommences and continues posteriorly in a normal manner. The scutes in the deformed portion were laid down normally, i.e., inserted anteriorly, with the posterior portion free and overlapping the anterior edge of the next scute.—*John M. Duffy, Marine Resources Operations, California Department of Fish and Game. Accepted January 1968.*

OBSERVATION OF STRIPED BASS SPAWNING IN THE SACRAMENTO RIVER

The only published account of striped bass (*Morone saxatilis*) spawning in California is that of Woodhull (1947).

We had the opportunity to make additional observations on the afternoon of June 9, 1967, when we investigated a report of striped bass spawning at Steiner Bend, 20 miles north of Knights Landing on the Sacramento River.

Groups of three to six bass were observed splashing in the middle of the river. In addition to these splashing and spawning activities or "rock fights" (this term originates on the Atlantic Coast, where striped bass are called "rockfish"), there was an aggregation of large striped bass forming a 4- to 8-ft-wide band along the east bank of the river. This band, which was formed by several thousand fish, was about 1,000 yards long and was located 6 to 12 ft from the river bank.

Some of these fish were in water as shallow as 1 ft and all were out of the main river current. Maintenance of position in the current was by slow swimming movements. At times the dorsal and caudal fins were out of the water. Occasionally, a fish was observed on its back

with its white ventral surface up and head down at a 30- to 45-degree angle.

The fish in this aggregation appeared to be resting and relatively inactive. It was not possible to observe clearly fish leaving the aggregation to participate in the rock fights, although this probably occurred. No rock fights were observed in the aggregation, although some occurred near it.

Several anglers caught limits from the aggregation along the river bank using cut sardines, indicating that some of these fish would feed. Milt from captured males was strewn abundantly on the bank.

The spawning activities were first reported on June 7. On June 10, the aggregation had dispersed and only three rock fights were observed in 1½ hours in contrast to the previous day, when as many as four or five fights were observed simultaneously. The water temperature on June 10 was 62 F.

The number of eggs sampled by the Delta Fish and Wildlife Protection Study's pumps at Ryde reached a dramatic high on June 11 and 12—about 2 days after our observation (Jerry L. Turner, pers. comm.). This station is located approximately 85 miles below Steiner Bend. From the age of the eggs and the river flow rate, we concluded that the origin of these eggs was in the area of our observation.

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BOOK REVIEWS

Fisheries Year Book and Directory 1967-68

Edited by Harry F. Tysser; British Continental Press Ltd., London, 1967; 443 p., illustrated. £ 2.

In addition to the many regular features in this year's *Fisheries Year Book and Directory*, such topical subjects as air transport of fish, mechanical unloading of fresh fish, and pumping fish from nets to vessel have been included.

The regular features having been enlarged, present interesting developments in fisheries research in the United Kingdom, developments in fish processing, preservation and handling, and recent innovations in vessel construction and equipment.

In the world survey section, a summary of fishery statistics for 30 countries is presented. These data are concerned with fish catches, exports, imports, consumption, and developments.

The reference section contains a fish supply calendar, a dictionary of fish names in eight languages, organizations and trade associations in the industry and related trades, and lists specialized publications.

Particulars are presented for nearly 6,000 firms in the world directory section. These firms are engaged in fishing; processing and distribution of fresh, frozen, and canned fish; and other seafoods. Suppliers of vessels, machinery, equipment and materials used in the fishing industry are included. A classified buying guide for all types of fish, shellfish, and fishing equipment also is presented.

The timely special feature chapters and the wide range of information presented in this book make it a valuable reference to persons engaged in all phases of the fishing industry.—*J. Gary Smith.*

Fish Quality at Sea

Edited by World Fishing and the White Fish Authority Staff; Grampian Press Ltd., London, 1966; vi + 129 p., illustrated. £ 5-5-0 (\$16.00)

The official proceedings of the Conference on the Design of Fishing Vessels and the Equipment in Relation to the Improvement of Quality are published in this book. Divided into four sessions, the papers and discussions cover a variety of interesting topics related to improving quality of fishery products.

The first three sessions dealt with the technology of handling and stowing methods aboard conventional side and stern trawlers, icing, chilling, and superchilling methods were discussed. Ways of improving these methods in an effort to maintain the catch at a constant temperature were explored. The merits of freezing trawlers and their equipment requirements received considerable attention since the larger, far seas vessels are gaining in popularity. The conclusions drawn from these sessions indicate that once a suitable ice is perfected; a standardized box is approved; improved automation techniques for handling, stowing and unloading the catch are developed; and practical freezer units are designed, the quality of fish can be preserved aboard fishing vessels.

In the final session, less emphasis was given to problems of technology and there were more considerations of presenting vessel operators with practical means of maintaining fish quality. Topics ranged from freezing fillets at sea, offal processing (slightly out of context with the other presentations, but nevertheless interesting), and design of motherships and attendant vessels to methods of transferring fish catches at sea.

Although the information in this book relates primarily to the northeastern Atlantic fisheries, many of the topics should be of interest to segments of the American fishing industry. In particular, there are considerations for the fishing vessel operator, ship builder and designer, food technologist, processor, fishing gear and equipment specialist, and the fishery biologist interested in optimum fishery utilization and development. I believe, however, that the wealth of information presented on this most important subject unfortunately will receive limited distribution due to the high price of the book. Hopefully, through reprinting or the presentation of a similar conference for American industry, this information may be disseminated to its proper audience.—*J. Gary Smith.*

Modern Deep Sea Trawling Gear

By John Garner; Fishing News (Books) Ltd., London, 1967; 79 p., illustrated. £ 2 2s.

In the tradition of his past successes of writing fundamental and practical books on trawling, John Garner's present accomplishment is a welcome addition. The clarity and simplicity of expression and ample illustrations, one-third of which are fold-outs, present the evolution of trawling gear from its beginning to current designs for modern stern trawlers.

There are seven chapters outlining in detail the empirical development of trawl gear, the design and operation of side trawl gear, and the design and operation of stern trawl gear. Garner presents a comparison of side trawl gear and stern trawl gear. The design and efficiency of otter boards are discussed, as well as the development of gear for stern trawlers. General notes on operational procedures and assemblies also are presented. In the final chapter, the trawling gears of medium-class stern trawlers are discussed.

Three appendices have been included which analyze the gear used by Aberdeen trawlers, discuss the apprentice, and note future applications of trawling.

In my opinion, this book is a must for anyone, regardless of trawling experience, who wishes to understand the fundamental principles and practical details of the design and operation of modern deep sea trawling gear.—*J. Gary Smith.*

Fishing Boats of the World: 3

Edited by Jan-Olof Traung; Fishing News (Books) Ltd., London, 1967; 648 + xlii p., illustrated. £ 7.15.0 (\$23.50).

This book is the third volume in a series resulting from FAO Congresses on Fishing Boats of the World. The third Fishing Boat Congress was held in Goteburg, Sweden, in October 1965 and was attended by over 300 fisheries experts from 40 nations.

At this meeting particular attention was devoted to the design and study of the smaller inshore and near-water fishing boats, mostly under 150 tons, in contrast to the recent emphasis on large distant-water factory type vessels.

A total of 174 persons contributed material to this well-organized volume, which is in itself a library of material on small fishing boat design. *Fishing Boats of the World: 3* is divided into six parts, which enables the reader to easily find the information he may be looking for at any one time. Contents range from the social and economic problems of boat building and mechanization of small boats in developing countries to the evaluation of the most recent trends in vessel design.

One of the primary purposes of the book was to cover the problems of the developing countries and determine how modern technology can be used to their advantage.

While the use of modern boat building materials, such as fiberglass reinforced plastic and aluminum, and the intricacies of structural design are gone into in some detail, an evaluation of the advantages and disadvantages of indigenous small craft design was also made. While it was found important to develop and utilize new designs and materials for fishing craft, it was pointed out that many times there were distinct advantages in modifying traditional designs and using wood properly before going into more sophisticated construction techniques.

It was shown that in some of the highly developed countries certain inshore fisheries can still be carried out efficiently by traditional fishing craft but only if the modern materials such as plastics and fiberglass are used in their construction. Examples of these adaptations were given for the lavar and shellfish boats used in Japan and the unique surf skiffs designed for use along the southern California Coast.

It would be impossible to describe all of the details of a book of this stature. This book, along with others in the series, constitutes one of the most useful collections of material on fishing boat design and utilization ever written and should be included in any complete fisheries library.—*Emil J. Smith, Jr.*

Marine Molluscs as Hosts for Symbioses (Advances in Marine Biology, Volume 5)

By Thomas C. Cheng; edited by Sir Frederick S. Russell; Academic Press Inc., London and New York, 1967; xiii + 424 p., profusely illustrated. 100s. \$17.50.

As the first of its kind, this work is a welcome addition to the field of marine biology.

This book is divided into two sections. The first is concerned with an analysis of the factors involved in symbiosis (includes parasitism, mutualism, commensalism, and phoresis), beginning with the host-symbiont contact, continuing with the establishment of the symbiont, and concluding with the departure of the symbiont from the host. Excellent discussions of molluscan internal defense mechanisms, pathology, and physiology of intramolluscan parasites are given. The second section of the book is concerned with systematics, life cycles, ecology, and pathology of the known symbionts of commercially important marine molluscs.

The book is meticulously done, easily read, and provides a wealth of information which would be virtually unavailable to the average person. The excellent photomicrographs, drawings, and extensive bibliography are additional features which the worker or student will find beneficial. By bringing together all known facts concerning the symbionts of commercially important marine molluscs the author, T. C. Cheng, has provided a guideline for future work to elucidate upon host-symbiont relations.

This text should be considered a must for students, teachers, and biologists interested in malacology, parasitology, pathology, invertebrate physiology, and ecology.—*S. C. Katkansky.*

Parasites of North American Freshwater Fishes

By Glenn L. Hoffman; University of California Press, Berkeley and Los Angeles, 1967; x + 486 p., illustrated. \$15.

Glenn L. Hoffman is known and recognized as a competent and experienced parasitologist who has made numerous contributions to the field of fish parasitology. This work on parasites of North American freshwater fishes is the best and most comprehensive effort yet produced. The contents, which are presented in a scholarly and readable manner, include chapters on Public Health Aspects of Fish Parasites, Algae and Fungi, Protozoa, Monogenetic Trematodes, Adult Digenetic Trematodes, Metacercarial Trematodes, Cestodes, Nematodes, Acanthocephala, Leeches, Parasitic Copepods, and end with a host-parasite check list.

There are 60 pages of bibliography which provide a very good guide to the fish parasite literature. Over 200 clear and well reproduced line drawings will be an aid to those working in the field.

The fish and parasite check list appears to have few errors and omissions and will be quite useful to the student, fishery worker, and researcher.

This volume will be greatly appreciated by fish disease specialists and will as well be a useful addition to the libraries of fishery workers, students, and researchers in the field of fish parasites.—*Harold Wolf.*

Fossil Shark and Fish Remains of North America

By Gerard R. Case; published by the author, 1967; 20 p., 102 figs. \$2.25 paperback. Sold only by the author: Gerard R. Case, 225 St. Paul's Avenue, Jersey City, N.J. 07306.

The title of this small booklet is quite misleading. Omissions are the rule, misidentifications are numerous, and contrary to the author's statement that the nomenclature is as up-to-date as possible, it is not! The photographs are generally excellent, and the treatment given to Cretaceous and older material is quite good, but other illustrations and the fossil coverage for the latest 75 million years of the earth's history can stand improvement.

The well-known and extremely diverse Eocene ichthyofauna from the Green River and Bridger formations has been covered by five photos of herring and two of bass. California's extensive Miocene elasmobranch fauna, including that of Shark Tooth Hill, is represented by two photos of shark teeth, one of which (Fig. 69) has been misidentified. Our well-documented, rich Miocene teleost fauna is glossed over with a photo of a single clupeid from Lompoc diatomite and a clupeid scale from Gaviota State Park—both erroneously placed in the Pliocene. Freshwater fossil fishes, of which more than 100 species of Miocene age and younger are known, are represented by a single photo of a stickleback (Fig. 90) with a misspelled specific name. Dozens of fossil scales have been described by an assortment of workers, but only two of these have been pictured (Fig. 74 listed as *Atractosteus* which is a synonym of *Lepisosteus*, and Fig. 100 given as *Ganolytes* sp. when only a single species, *cameo*, is known). Otoliths have been left out entirely, even though they are extremely abundant, and some were described from North America as long ago as 1888. In fact, in many marine deposits laid down during the last 125 million

years, 100 or more identifiable teleost otoliths can be found for every tooth of a shark, skate, or ray.

Lamna teeth have been called *Otodus* and *Odontaspis*, *Odontaspis* has been called *Lamna*, *Isurus* has been called *Oxyrhina*, *Carcharias* is used for *Carcharhinus*, and so on.

The bibliography overlooks the extremely important contributions of Louis Agassiz, Lore Rose David, Don L. Frizzell, David Starr Jordan, E. Koken, Maurice Leriche, Robert Rush Miller, and Teruya Uyeno, to name but a few.

There is still a great need in this country for a book on fossil fish remains of North America.—*John E. Fitch.*

External and Internal Characters, Horizontal and Vertical Distribution, Luminescence, and Food of the Dwarf Pelagic Shark, *Euprotomierus bispinatus*

By Carl L. Hubbs, Tamotsu Iwai, and Kiyomatsu Matsubara; University of California Press, Berkeley and Los Angeles, 1967; vi + 81 p., illustrated. Paper \$2.50.

The title of this publication is accurate insofar as it goes, but it fails to mention that many detailed comparisons are made between *Euprotomierus* and a "supposedly very close relative", *Isistius brasiliensis*. The authors retain *Euprotomierus* and *Isistius* as distinct genera in the subfamily Dalatiinae of the family Squalidae, but it is obvious that the differences they found in comparing the two were of sufficient magnitude to cast doubt on the adequacy of this taxonomic treatment.

Only eight specimens of *Euprotomierus* (appropriately termed pigmy shark) were known prior to 1951; 37 individuals are listed in this publication—14 for the first time. Its ability to luminesce, its neutral buoyancy, and its food habits are used as evidence to support the hypothesis that the pigmy shark is a bathypelagic species that undertakes vertical, presumably diurnal, migrations. The authors further postulate that *Euprotomierus* "aggregates, and probably schools".

Few shark species have had their life history, food habits, anatomy, and other features as thoroughly investigated as *Euprotomierus* in this small publication.—*John E. Fitch.*

Atlas of the Errantiate Polychaetous Annelids from California

By Olga Hartman; Allan Hancock Foundation, University of Southern California, Los Angeles, 1968; 828 p., illustrated. \$20.

Most of the descriptions of polychaetes or marine annelids from the northeast Pacific Ocean are concealed in many short research papers, not generally available to biologists or others who may wish to acquaint themselves with at least the commonly encountered animals along the seashores. The littoral and sublittoral zones of California, like other parts of the northeast Pacific, abound in an astounding diversity of marine life, much of which consists of marine annelid worms, existing in crevices, under stones, among kelps, on or in other animals, and in other accessible recesses. The startling beauty of color, form, and movement of living worms can be appreciated by observing them in marine aquaria, where they adapt themselves quickly to reconstruct niches, restore lost body parts, deposit egg capsules if mature, and perform other natural phenomena which are normal to the species.

Some of the most beautiful and common of these worms are among the best represented families; they include the polynoids with 43 species, the syllids with 41, the phyllodoceids with 34, and the nereids with 29. In all, there are 339 species of Errantia in 128 genera and 29 families. More than half of them are considered endemic to California south to western Mexico; over half of the remaining half are common also to the north Pacific, and fewer than 25% can be considered cosmopolitan, or existing in Pacific and Atlantic oceans. This high degree of endemism (more than 50%) may not be real, for when the annelids of other parts of the Pacific are better known, it may be found that many species exist throughout this realm.

The *Atlas* brings together the accumulated data for 339 species of polychaetes recorded from California. A systematic list is followed by a glossary, which defines terms most commonly used. Keys are given to genera and species within each family. A key to families has been omitted because experience has shown that the beginner invariably goes astray, since family characters are based chiefly on internal characters which the beginner is unable to interpret.

Each species is diagnosed on a separate page, with illustrations of significant parts; more extensive distribution is indicated, and ecological data are shown on

an outline map of the State. The accepted specific names are those used in my *Catalogue of the Polychaetous Annelids of the World* (Hancock Found. Publ., Oceans, Pap., 23). The *Errantia* is the first of 2 volumes; the second, in preparation, will include the *Sedentaria* and other aberrant groups, and will contain about as many species.

The *Atlas* should be useful not only to the biologist, but to commercial fisheries, where basic foods of fishes are concerned, and to industrial interests, in which pollution problems can be partly solved by encouraging the conversion of wastes and turnover of sediments by certain marine polychaete worms.—*Olga Hartman*.

Algal Cultures and Phytoplankton Ecology

By G. E. Fogg; The University of Wisconsin Press, Madison, 1966; xiii + 126 p., illustrated. \$5.50.

Although algal literature is extensive, G. E. Fogg presents an enlightening overview of this field. His book is short and to the point, without being too oversimplified. He reviews much of the pertinent algal literature and draws many connections between laboratory and field studies. In so doing, he raises as many questions as he attempts to answer.

Algology is especially important to fisheries biology since algae are the key link between electromagnetic radiation, inorganic minerals, and the fish on the end of your line. Fishery biologists have, by and large, overlooked the relationship between algae and fish production because of the many very complicated problems involved. However, as our understanding of these processes increases, we may evolve a more definitive view of this relationship. Indeed, such a view is necessary before we can truly manage a fishery.

Fogg discusses algal growth patterns as observed in the laboratory and field, phytoplankton periodicity, phytoplankton distribution, and seasonal succession. This book is an excellent reference source and introduction to algology. Scientific jargon is kept to a minimum for the benefit of layman and biologist alike.—*Arlo W. Fast*.

Being Your Own Wilderness Doctor

By E. Russel Kodet and Bradford Angier; Stackpole Books, Harrisburg, Pa., 1968; 127 p., illustrated. \$3.95.

This book is definitely not a first aid guide but is aimed at the person traveling in back country where medical help is not available.

In my opinion this book would be more useful to individuals living in very remote areas rather than to most back-country vacationists. I doubt if many vacationists would utilize the suturing techniques or the reductions of fractures and dislocations that are described.

I would take exception to the statement that tourniquets to stop arterial bleeding should be loosened every 8 to 10 minutes. This was the old method advocated by the Red Cross but has been discarded because of the probability that the patient would die from blood loss. If a tourniquet is necessary it is usually a decision to sacrifice a limb to save a life and it should not be removed until the artery is clamped off. The suggested items to include in a medical kit are helpful.

I think the book would have been improved if ground to air signals for assistance were included.

One additional caution is that by going beyond accepted first aid, you probably increase the danger of law suits.—*Wallace G. Macgregor*.

Fishing With The Fly: Sketches by Lovers of the Art with Illustrations of Standard Flies

Collected by Charles F. Orvis and A. Nelson Cheney; Charles E. Tuttle Co., Inc., Rutland, Vermont, 1967; xii + 328 p., + 15 color plates. \$7.50.

From the quick reading of the title, one would think that this is a book dealing with fly fishing and how to do it; such is not the case.

Fishing With The Fly was originally published in 1886. It is the compiled works of twenty-four "Lovers of the Art", about their love—fishing. These works cover the complete area of angling from "Fly Casting for Salmon" to the "Poetry of Fly-Fishing" and suggestions on tackle to use.

It is of interest to note the emphasis on fishing in the "old days" in comparison with fishing today. The well-written odes and poems bring nostalgia to the reader for

the days when fishing was true sport and the catching of fish not the primary importance on a fishing trip. Perhaps if more of today's anglers had the more aesthetic view of our predecessors, we would not have the problems we do today.

The 15 color plates are of various types of flies that were in use during the latter half of the nineteenth century. The modern day angler will not see many of the patterns and types of flies that are being used today.

The book gives a person a retrospect of anglers as they use to be. Would that there were more of this type of angler today.—*Hugh L. Thomas.*

Modern ABC's of Ice Fishing

By Jerry Chiappetta; Stackpole Books, Harrisburg, Pa., 1966; 176 p., photographs and black-and-white illustrations. \$4.95.

Handbook of Fishes of Kansas

By Frank B. Cross; University of Kansas, Lawrence, Kansas, 1967; 357 p., 4 colored plates, 20 numbered figures, and other illustrations. \$5.00 cloth, \$3.50 paper.

Although I am particularly attentive to fish and wildlife publications about Kansas, where, as a youth, I spent many enjoyable hours fishing and hunting, I unequivocally recommend this book as a fine supplement to fishery literature. It is in the mode of *The Fishes of Ohio* and others.

The expressed purpose of this handbook "is to provide means for identifying fishes found in Kansas, information about their distribution within the state, and general accounts of their habits." The format includes a general treatment of the history and distribution of Kansas fishes, which are primarily fluviatile, relating them to the two major stream systems in the state, the Kansas and Arkansas Rivers. In order of sequence, the handbook is comprised of illustrations of key characteristics, a glossary of key characteristics, a key to families of fishes, and species accounts.

The scientific and vernacular names used by the author are those in *A List of Common and Scientific Names of Fishes from the United States and Canada* (Amer. Fish Soc., Spec. Publ. 2, second edition, 1960). The sequence in which the families appear in the text follows the arrangement proposed in *Phyletic Studies of Teleostean Fishes, with a Provisional Classification of Living Forms*, by P. H. Greenwood, D. E. Rosen, S. H. Weitzman, and G. S. Myers (Bull. Amer. Mus. Nat. Hist., 131 (4): 339-456).

In addition to a key to families, a key to species is presented when two or more species common to a family are described. The keys form a sequence of couplets (paired, contrasting statements). I had no trouble keying out several common centrarchids and ictalurids, but persons lacking some exposure to taxonomy might encounter difficulties.

Each species account contains an illustration of the fish, its descriptive characters, a map of its known distribution, a list of literature references, and a general discussion of the status of the species in the state. Although the fish are more colorful in the plates than they normally appear in nature, the quality of these and other renderings is good.

Life history information in the species accounts is fairly comprehensive and often applies wherever the species is found. The author does make some rather sweeping generalities based on his personal experiences with various species. Instead of his sometimes restricted accounts more space could have been dedicated to management practices, information on growth rates of some of the species, and data on fish harvest.—*Larry K. Puckett.*

Ecology and Resource Management: A Quantitative Approach

By Kenneth E. F. Watt; McGraw-Hill Book Company, New York, 1968; xii + 450 p., illustrated. \$14.50.

This book presents a general theory of resource management which can be used in dealing with all kinds of problems, from oceanic fisheries to forest insect pest control. It explains techniques that are ushering in a new era in the management of complex resource optimization problems, specifically new methods of applied mathematics and computer simulation. Each field of resource management has much to learn from the others and this book brings together a common body of theory and methods. Each major problem is discussed, using that resource which best illustrates the problem and for which documentation is most complete.

The book is divided into two main sections. The first has for its theme ecological principles, management theories derived from these principles, and case studies demonstrating their application. It must be this first section to which Dr. Watt refers in his preface "... it is my fervent wish that the book will be read by laymen . . ." because the second section considers the operations involved in scientific resource management; measurement, analysis, description, simulation, and optimization of the system. Almost every other page of the second section contains a statistical formula, differential equation, or computer language sufficient to discourage any layman from doing much more than thumbing through the pages. As the author states, the book could be used in courses in biomathematics or biostatistics.

Each chapter is well documented and contains an extensive reference list, providing the reader with several sources of follow-up reading.

A few of the subjects discussed include: growth of the world's human population, deer management, Great Lakes sea lamprey problem, hatcheries supplementing natural reproduction, water resources, buffalo, salmon, chaparral, population ecology, community energetics, maximization of productivity, density-dependent and density-independent factors, overexploitation, biological wave phenomena, application of Fortran, science of sampling, iterative regression and curve fitting, systems analysis, developing large-scale models, simulation, dynamic programming, and optimum allocation.

I do not recommend this book to biologists or resource managers unfamiliar with statistical methods and introductory calculus. To those versed in these disciplines I highly recommend reading the book to gain insight into an enlightening approach to resource management.—*James W. Burns.*

A Different Kind of Country

By Raymond F. Dasmann; The Macmillan Co., New York, 1968; x + 276 p., illustrated. \$5.95.

The theme of this book is an examination of the role of diversity as a factor in the quality of human environments. It is profusely illustrated and is easy to read.

The author makes a strong plea for retaining much of the diverse country that still exists and creating diversity in the things we build. He discusses the modern pressures that are forcing worldwide uniformity and points out the danger of a uniform world that is uniformly uninteresting and of low quality.

The book's appeal may be mainly to people who already tend to agree with the views of the author, but it is valuable because of its power to rekindle the enthusiasm of all who ponder the world's future. Although it may not be read by those who need its message most, it will provide additional ammunition for those already working for a high quality human environment.—*James D. Stokes.*

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Notice is hereby given that the Fish and Game Commission shall meet on October 4, 1968, at 10 a.m., in the Auditorium, Employment Building, 722 Capitol Mall, Sacramento, California, to receive recommendations from its own officers and employees, from the Department and other public agencies, from organizations of private citizens, and from any interested groups as to what, if any, regulations should be made relating to fish, amphibia, and reptiles, or any species or subspecies thereof.

Notice is hereby given that the Fish and Game Commission shall meet at 10 a.m. on November 1, 1968, in the Multi-Purpose Room, Third Floor, New Annex, Courthouse, Redding, California, for public discussion of and presentation of objections to, the proposals presented to the Commission on October 4, 1968, and after considering such discussion and objections, the Commission, at the meeting, shall announce the regulations which it proposes to make relating to fish, amphibia, and reptiles.

Notice is hereby given that the Fish and Game Commission shall meet on December 6, 1968, at 10 a.m. in Room 1138, New State Building, 107 South Broadway, Los Angeles, California, to hear and consider any objections to its determinations or proposed orders in relation to fish, amphibia, and reptiles, or any species or subspecies thereof for the 1969 sport fishing season, such determinations and orders resulting from the hearings held on October 4 and November 1, 1968.

Fish and Game Commission
Leslie F. Edgerton
Executive Secretary

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